EFFECT OF COMPOSITION ON THE RHEOLOGICAL PROPERTIES OF ASPHALT CEMENT

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EFFECT OF COMPOSITION ON THE RHEOLOGICAL PROPERTIES OF ASPHALT CEMENT

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SUMMARY

This work was funded by CANMET, Department of Energy Mines and Resources, Canada to relate the rheological properties of asphalt to its composition. A further objective of this study was to develop guidelines for selecting crude oils for asphalt manufacture.

The Corbett separation method was used to obtain compound-type fractions from Cold Lake deasphalted oil. The fractions (saturates, naphthene-aromatics, propane precipitated asphalt) were then blended with selected vacuum residues to produce 150/200 penetration asphalts. The changes in properties with respect to the original asphalt were determined.

The properties examined were the Penetration Index, the Pen-Vis Number, the low temperature stiffness, the ductility and the glass transition temperature. The Penetration Index was shown to correlate with the asphaltenes/(wax + polar aromatic) ratio (less temperature susceptible/more temperature susceptible ratio).

The saturates fraction is the only compound-type that increases the Pen-Vis Number when blended into asphalt. Air blowing does not affect the Pen-Vis Number significantly. All compound-type fractions reduce the stiffness at -20°C due mainly to compositional change but more significantly with the saturates. Both the low temperature stiffness and ductility are influenced by the Colloidal Instability Index. The glass transition temperature is shown to correlate with the polar aromatics content but the Penetration Index does not.

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Résumé

Cette étude subventionnée par CANMET, Ministère de l'Energie des Mines et des Ressources, Canada a pour but d'examiner l'influence de la composition d'un bitume sur ses propriétés rhéologiques. L'objectif de cette étude est de développer des corrélations permettant de prédire le comportement rhéologique d'un bitume à partir de sa composition et d'élaborer des critères de sélection de bruts pour la préparation de bitumes.

Les composés types utilisés dans cette étude sont séparés à partir d'une huile déasphaltée de Cold Lake. La méthode de Corbett est appropriée pour la séparation d'un bitume en ses composés types. Ces fractions (huiles saturées, huiles naphthénique aromatiques et asphaltes) sont ensuite mélangés avec des résidus de distillation pour produire des bitumes de pénétration 150/200. Les changements de propriétés par rapport au bitume original sont ensuite étudiés.

Les propriétés examinées sont l'indice de pénétration, le PVN, la rigidité à basse température, la ductilité et la température de transition vitreuse. Nous démontrons que l'indice de pénétration est reliée au rapport asphaltènes/paraffines + composés polaires. Les huiles saturées sont la seule fraction qui augmente le PVN d'un bitume. Le soufflage d'un bitume a très peu d'influence sur le PVN. Tous les composés types réduisent la rigidité à -20°C; par contre les huiles saturées ont beaucoup plus d'influence. Nous démontrons que la rigidité à basse température et la ductilité sont reliés à l'indice d'instabilité colloidale et que la température de transition vitreuse est reliée à la teneur en composés polaires mais non à l'indice de pénétration.

1. INTRODUCTION

The influence of the composition of asphalts has been recognized for a long time as an important factor in controlling the performance of such materials. Among the numerous characteristics selected to assess asphalt performance, the rheological properties of pure asphalt or mixes is the most important. The rheological properties of asphalts have been always associated with their composition. However, in order to utilize effectively the compositional data, more definitive correlations between composition and properties are needed. This information will allow the selection of asphalt cement to give desired performance, and would provide pertinent data for crude selection for asphalt manufacture. Both would lead to better pavement durability.

Asphalt is a very complex mixture of compounds which can be separated into four generic fractions: saturates, naphthene-aromatics, polar aromatics and asphaltenes. Depending upon its composition and stress level or shear rate, asphalt could have a Newtonian or non-Newtonian behaviour. Asphalts with Newtonian flow (sol type) are those which have directionally lower asphaltene content, high ductility and are temperature susceptible (low Penetration Index). On the other hand, asphalts with non-Newtonian flow (gel type) are characterized by a more colloidal structure resulting from higher asphaltene content, low ductility and low temperature susceptibility (high Penetration Index).

Although gel type asphalts may be preferred to sol types because of its higher Penetration Index, which is associated with better low temperature performance and low rutting susceptibility, current specifications exclude them by requiring a minimum ductility and/or limiting wax content. These two properties are associated with asphalt heterogeneity.

It is the objective of this study to relate composition of asphalt with their physical and rheological properties. This was done by blending selected fractions (saturates, naphthene-aromatics and propane precipitated asphalt, which was used as an asphaltene concentrate) with various vacuum residues to produce a 150/200 penetration grade asphalts, and observing the change in properties with respect to the original asphalt.

The fractions used in this study were obtained from Cold Lake asphalt because it does not contain wax, which would affect the composition and properties of the saturates and naphthene-aromatics fractions. Cold Lake asphalt was first propane deasphalted to produce a deasphalted oil (DAO) and propane precipitated asphalt. The DAO was separated according to the Corbett separation method (ASTM D4124) to produce the saturates and naphthene-aromatics used in this study.

Eight different asphalt blends were prepared from Cold Lake, visbroken Cold Lake and Peace River residues and correlations of the composition with Penetration Index, Pen-Vis Number, ductility, glass transition temperature and creep compliance were determined. The composition, Penetration Index and PVN of asphalt produced from other crude sources have also been included in the study.

2. DEASPHALTING AND SEPARATION OF THE COMPOUND-TYPE FRACTIONS

The compound-type fractions used in this study (saturates, naphthene-aromatics and propane precipitated asphalt (PPA)) were obtained by first deasphalting a Cold Lake 150/200 penetration asphalt to produce DAO and a propane precipitated asphaltic fraction. The DAO was submitted to a scaled up Corbett separation (ASTM D4124) to produce the saturates and naphthene-aromatics. The polar aromatics were not used in this study. A description of the deasphalting and chromatographic separation procedures are presented in sections 2.1 and 2.2.

2.1 Deasphalting Procedure and DAO Composition

A sample of Cold Lake 150/200 penetration asphalt was deasphalted to provide approximately 1.5 L of deasphalted oil (DAO) to be further separated into saturates, naphthene-aromatics and polar aromatics by chromatographic procedure.

The deasphalting work was carried out in a continuous pilot plant deasphalting unit using propane as the solvent. The heart of the unit is an electrically heated tower approximately 1.2 meter in height. The oil feed was pumped into the tower near the top while the solvent is forced into the tower near the bottom using differential pressure from a blowcase. The opposing flows (due to different densities) and a mixer provide the necessary contacting extraction of the deasphalted oil (DAO). The solvent rich DAO phase is removed from the top of the tower and the solvent lean asphalt phase is removed from the bottom. The two streams are then stripped of solvent.

The tower top temperature, temperature gradient, mixing speed, feed inlet position and solvent flow rate (treat) are all controlled to provide the desired quality DAO from a given feed. A DAO density target of 0.96 kg/L was selected to provide acceptable DAO quality. The feed, DAO and asphalt properties are presented in Table 1. Since the propane precipitate asphalt, (PPA) was used as blending component, the composition has been determined by the ASTM D4124 procedure. The compositional data are presented in Table 1.

The results show that deasphalting does not selectively separate the polar aromatics and asphaltenes from the saturates and naphthene-aromatics as it was originally thought. However, it allows production of a large amount of asphaltene free fraction (DAO). The composition of the PPA has been taken into consideration in the interpretation of the results.

2.2 Compound-Type Separation of the DAO

The Cold Lake DAO prepared in Section 2.1 was separated into saturates, naphthene-aromatics and polar aromatics according to the ASTM D4124 procedure. However, in order to prepare sufficient material for blending with asphalt the following scaled up procedure has been used.

In a typical separation, 125 g of DAO was percolated through a glass chromatographic column (170 cm high x 7 cm diameter) filled with 4500 g of activated alumina. The saturates were eluted using 2000 ml of n-heptane. The naphthene-aromatics were eluted with 4000 ml toluene. The saturates/solvent mixture was colourless while the naphthene-aromatics/solvent mixture was light orange. A schematic of the separation is presented in Figure 1.

The purity of the fractions were evaluated by FTIR. The IR spectra of the fractions are presented in Figures 2 and 3. Although the spectra look similar, no aromatics were detected in the saturates fraction as shown by the absence of the C=C band at 1600 cm^{-1} and the C-C-H band in the 3000 cm^{-1} area. Conversely, no polar aromatics were found in the naphthene-aromatics fraction as shown by the absence of OH and NH bands near 3500 cm^{-1} and C=O band at 1700 cm^{-1}.

3. EFFECT OF BLENDING COMPOUND-TYPE FRACTIONS ON THE COMPOSITION

Four different 150/200 penetration asphalts made from Peace River, Cold Lake and visbroken Cold Lake crudes have been used as reference samples. The other samples (total of four) were prepared by blending 10 to 15 wt% of selected compound-type fractions with vacuum residues from the same crude as the reference samples to produce 150/200 penetration grade asphalt. The samples used in this study are described in Table 2. In order to correlate the composition with the rheological properties it was important to use samples of the same penetration grade.

The effect of blending a given compound-type fraction on the composition of the asphalt determined by ASTM D4124 is presented in Table 3.

3.1 Effect of Adding Naphthene-Aromatics on the Composition

Blending naphthene-aromatics with Peace River vacuum residues affects the composition significantly (Table 3). A fairly good agreement is found between the calculated and actual saturates and asphaltenes contents. However, some of the naphthene-aromatics interact with polar aromatics and asphaltenes leading to an increase in the polar aromatics fraction. The sum of the naphthene-aromatics & polar aromatics is similar in both cases. Although the naphthene-aromatic content is lower than expected, it is increased relative to the saturates content, which provides the desirable compositional change.

In the visbroken Cold Lake case, good agreement of the calculated and found overall composition is observed. Visbreaking is known (1) to cleave alkyl side chains and heteroatom bond which could explain the lack of association of the naphthene-aromatics with the polar aromatics.

3.2 Effect of Adding Saturates on the Composition

Blending the saturates fraction with Cold Lake vacuum residue also affects the composition significantly (Table 3). The major changes are the increase of the asphaltenes content at the

expense of the polar aromatics content and the increase in saturates content. The saturates act as a paraffinic solvent, causing the polar aromatics to associate and leading to the formation of asphaltenes in the asphalt. In contrast to the effect of wax, (2) liquid saturates do not degrade the viscosity of Cold Lake asphalt (Table 4). They improve the properties of Cold Lake asphalt.

3.3 Effect of Adding Propane Precipitated Asphalt on the Composition

Blending the PPA with Peace River vacuum residue directionally increases the asphaltene content and decrease the polar aromatics content. This increase in asphaltene content should be reflected on the rheological properties of the asphalt. The presence of naphthene aromatics, polar aromatics and asphaltenes in the PPA appears to be responsible for not changing the naphthene-aromatics/polar aromatics ratio of Peace River as did adding naphthene-aromatics. Good agreement is found between the calculated and actual composition data.

4. EFFECT OF COMPOSITION ON THE RHEOLOGICAL PROPERTIES OF ASPHALT

Numerous papers have been published (3-8) on the relationship between composition and physical properties. However, to our knowledge none of the papers deal with changing composition of asphalt by blending a given compound-type fraction and observing the change as compared with the original material. We have selected the Corbett separation method (ASTM D4124) because the composition and physical properties of each compound-type fraction are distinctly different from each other, and which is a requirement to obtain good correlation between composition with rheological properties of asphalt. The properties and compositions of the eight asphalt samples examined in this study are presented in Table 4. These data will be discussed in the following sections.

Other 150/200 penetration asphalts produced from other crude sources (Table 5) having different composition, Penetration Index from -1.0 to -2.6 and PVN from -0.20 to -1.16 have been included to provide better correlation of composition with some rheological properties.

4.1 Temperature Susceptibility

4.1.1 Penetration Index

The temperature susceptibility of asphalt cement is one of the most important properties associated with the low temperature performance of asphalt pavement. Asphalt cement with low temperature susceptibility is the most desirable because it has better resistance to low temperature pavement cracking.

The temperature susceptibility of an asphalt is the variation of its consistency (penetration or viscosity) with temperature. It is measured by the Penetration Index (PI). Asphalt with low temperature susceptibility has a high PI. The PI was first defined by Pfeiffer and Van Doormall (9) as a function of the

penetration versus temperature relationship. However, in their method of estimation the PI, they made the assumption that the penetration of all asphalts at the softening point is 800 mm/10. It was subsequently shown the the penetration of many asphalts differs significantly from 800 mm/10 (10, 11). The Penetration Index is then calculated from:

$$PI = \frac{20 - 500\,A}{50\,A + 1} \qquad (1)$$

$$\text{where } A = \frac{\log_{10} Pen_{T2} - \log_{10} Pen_{T1}}{T_2 - T_1} \qquad (2)$$

The value of A is determined from a plot of log Penetration (100 g, 5 s) versus temperature.

We have shown in another study (2) that increasing the wax content of an asphalt decreases its PI. However, blending liquid saturates into asphalt increases significantly the PI (Tables 3 and 4). We believe this is largely due to the increase of asphaltene content resulting from the addition of the saturates which increase the association of the polar aromatics.

Blending naphthene-aromatics with Peace River residue and visbroken Cold Lake residue (Tables 3 and 4) does not affect the PI. However, blending the PPA with Peace River residue increases the asphaltene content at the expense of the polar aromatics (Table 3) and increased the PI compared to the reference sample. Air blowing also increases significantly the PI from -1.9 (Peace River) to -0.13 (air blown Peace River) which is attributed to the increase of asphaltene content from 9.6% to 14.2%. The results indicate that asphaltenes have low temperature susceptibility while polar aromatics are very temperature susceptible (3). This is consistent with result reported by Corbett (3) on temperature susceptibility of the generic fractions.

From these results it has been possible to correlate the composition of asphalts with the PI. Good correlation ($R^2 = 0.87$) of the PI with the asphaltenes/(wax + polar aromatics) ratio is shown in Figure 4. If wax is not included as a compound type in this relationship, a poorer correlation ($R^2 = 0.75$) is obtained. The graph shows that with increasing the asphaltenes content the PI increases. This is consistent with the air blowing data (eg. Peace River) where PI increases with asphaltene content. In this ratio the asphaltenes represent the least temperature susceptible compound-type and the wax and polar aromatics represent the most temperature susceptible components.

The visbroken samples do not fit in this correlation, probably because of the differences in the chemical structures resulting from this type of processing.

4.1.2 Pen-Vis Number

The Pen-Vis Number (PVN) has been proposed by McLeod (12) as an alternative to the Penetration Index for the determination of the temperature susceptibility of asphalt cements. It is calculated from the penetration at 25°C and the viscosity at 135°C using the following equation:

$$PVN = -1.5\ (L - \log_{10}\eta)/(L - M) \qquad (3)$$

where $L = 4.25800 - 0.79674 \log_{10}$ Pen;
$M = 3.46289 - 0.61094 \log_{10}$ Pen;
η = viscosity at 135°C, cSt

Although the PVN was intended to equal the PI so it could be used to estimate the stiffness of asphalts using the Van der Poel's nomograph (13), it has been demonstrated by Robertson (14) that there is no correlation between the PVN and the PI. Therefore the PVN can not be used to determine temperature susceptibility of asphalt cement in the service temperature region. However, the PVN provides a useful tool to measure the viscosity/penetration relationships of asphalts.

Blending saturates into Cold Lake asphalt (Table 4) increases its PVN significantly as a result of the asphaltene content increase at the expense of the polar aromatics content. However, the naphthene-aromatics do not change the PVN significantly. The PPA also does not affect the PVN of Peace River asphalt. A similar result is obtained for air blown Peace River asphalt. Although, air blowing increases the asphaltenes content, the polar aromatics content is not decreased as much as for Cold Lake asphalt, which can explain this behaviour.

Correlation of the PVN with asphalt composition is difficult since the viscosity seems to be affected by the asphaltenes/polar aromatics content, asphaltenes molecular weight and interactions of the polar components with the asphaltenes. However, the results suggest that increasing the asphaltene content and decreasing the polar aromatics would directionally increase the PVN.

5. RHEOLOGICAL BEHAVIOUR OF ASPHALTS

Asphalt is a viscoelastic material which behaves like an elastic solid at low temperature or short loading time and a viscous liquid at high temperatures or long loading times. A good performing asphalt must have the proper consistency over the whole range of temperatures to which the asphalt pavement is exposed. This is why an asphalt with low temperature susceptibility (high PI) is the most desirable.

The creep compliance is one of the most important rheological properties of asphalt cement. It has been identified as the property that could give an indication of pavement rutting under traffic loading conditions (15).

These rheological characteristics were determined by measuring the shear compliance J(t) versus loading time at -20°C using a sliding plate rheometer and the apparent viscosity versus shear rate at 60°C using a cone and plate viscometer. The procedure for the cone and plate measurements is described in ASTM D3205 while the modifications of the sliding plate rheometer method have been described by Gaw (16). In addition to these changes specimen plates made of an epoxy-fibreglass laminate were used for tests at -20°C because they have a coefficient of thermal expansion closer to the asphalts than aluminum, reducing the magnitude of thermal stresses developed when the specimen is cooled. Slow cooling of the specimens was used to minimize the thermal stresses. The maximum cooling rate used were:

Temperature Range	Cooling Rate
0 to -10°C	30°C/h
-10 to -20°C	12°C/h

With the sliding plate technique, a layer of 10 mm of asphalt is put between two plane parallel plates one of which is fixed while the other is subjected to a constant shear stress applied at a defined loading time (t = 0). From t = 0 the displacement of the loaded plate is recorded. From the shear stress (τ) and the time dependant strain (γ) the creep compliance is calculated using equations 4 to 6:

$$J(t) = \frac{\gamma(t)}{\tau} \qquad (4)$$

$$\text{where } \tau = L\,g/A \qquad (5)$$

$$\text{and } \gamma(t) = D(t)/W \qquad (6)$$

In equations (5) and (6), L is the applied load; g, the gravitational constant; A, the surface area of the plate; D(t), the deformation and W, the thickness of the specimen layer.

When a material is subjected to a constant strain, the initial stress will gradually decrease over time. Its value at any loading time is defined by the stress relaxation modulus. The shear modulus is given by:

$$G(t) = \frac{\tau(t)}{\gamma} \qquad (7)$$

The relation between the shear modulus and tensile relaxation modulus E(t) is given by:

$$E(t) = 2\,(1 + \mu)\,G(t) \qquad (8)$$

where μ is the Poisson ratio. For asphalts or viscoelastic liquids $\mu = 0.5$, which reduces the equation to:

$$E(t) = 3\,G(t) \qquad (9)$$

The shear modulus can be estimated from the shear compliance using the following approximate equation by:

$$G(t) = \frac{\sin(m\pi)}{m\pi J(t)} \qquad (10)$$

where m is the slope of log J versus log t

Van der Poel (13) defined a stiffness modulus given by the ratio of stress to strain in a tensile creep experiment:

$$S(t) = \frac{\sigma}{E(t)} \qquad (11)$$

The Van der Poel stiffness is related to the shear compliance by:

$$S(t) = 3/J(t) \qquad (12)$$

5.1 Low Temperature Properties

The creep compliance versus loading time at -20°C for the eight asphalt samples examined in this work is illustrated in the Appendix. The stiffness of the asphalt at a loading time of 500 sec at -20°C is compared (Table 6) to the Penetration Index and the Colloidal Instability Index (I_c). The latter is defined (17) as the ratio of the asphaltenes plus saturates to the sum of the resins (polar aromatics) and aromatics. It is represent as follows:

$$I_c = \frac{\text{saturates + asphaltenes}}{\text{naphthene-aromatics + polar aromatics}}$$

Blending naphthene-aromatics into Peace River and visbroken Cold Lake asphalt reduces the stiffness at -20°C slightly. However, blending with saturates, or air blowing, reduces the low temperature stiffness significantly compared to the reference sample.

Good correlation of the low temperature creep behavior with I_c is observed for asphalts from the same crude. The results show that the low temperature stiffness goes down with increasing I_c. A similar trend is observed for the Penetration Index (Figure 5); higher PI asphalts have lower stiffness at low temperature. A fairly good correlation of these two properties is obtained considering that these asphalts do not have the same penetration. These results are consistent with those reported by Robertson (15) on the correlation between low temperature stiffness and PI.

The apparent viscosity versus the shear rate for the asphalt samples examined in this work is illustrated in the Appendix and presented in Table 7. All the asphalts have near Newtonian behavior at 60°C (the viscosity does not change with the shear rate). Blending naphthene-aromatics, PPA or saturates with asphalt changed the viscosity level but not the rheological behavior compared to the reference sample. A determination at a lower temperature eg. 40°C would be required to observe differences in shear susceptibility among these asphalts. The viscosity difference between cone and plate

method and ASTM D2171 is due at least partly to difference in shearing conditions in the two tests.

5.2 Glass Transition Temperature

The glass transition temperature (T_g) has been determined by Differential Scanning Calorimetry (DSC). A typical thermogram for Cold Lake asphalt is presented in Figure 6. This technique is also used to determine the wax content of asphalt (18). The glass transition temperature of asphalt has been the object of several studies (18-20). Schmidt et al (20) were among the first to report on glass transitions.

In this study, the effect of composition on the T_g has been examined. The relations between the composition of asphalts and their T_g values were reported by Noel et al (18), Connor and Spiro (21) and Huynh et al (19). These authors showed that the T_g decreases with increasing paraffinic content. Furthermore, Huynh et al showed that longer the paraffinic chains in asphalt the lower is the T_g. All these studies indicate that the glass transition temperature is a very important property of asphalt cement. It corresponds to the temperature at which asphalt become brittle (glassy state).

Blending naphthene-aromatics with Peace River and Visbroken Cold Lake asphalt does not affect the T_g significantly (Table 4). However, air blowing increases the asphaltenes content at the expense of the polar aromatics which results in a lower T_g. A similar result is observed for blending saturates with Cold Lake asphalt. The saturates content is increased and the polar aromatics are significantly decreased as compared to the reference Cold Lake sample, and the T_g is decreased from -27°C to -35°C. The results show that the polar aromatics content has a large effect on the T_g. With increasing polar aromatics content, the T_g increases. A good correlation ($R^2 = 0.88$) was found between the T_g and the polar aromatics as shown in Figure 7.

Although in many cases it appears that higher PI values correspond to a lower T_g, a poor correlation ($R^2 = 0.16$) was observed between these properties. However, the difference in penetration between the asphalts contributes largely for this poor correlation. This is clearly illustrated by comparing Cold Lake asphalt with Peace River asphalt (Table 4). Peace River has a PI of -1.92 and a T_g of -36°C. Conversely, Cold Lake which has a better temperature susceptibility (PI = -0.98) has a higher T_g (-27°C).

5.3 Ductility

The ductility is determined by measuring the elongation of an asphalt specimen under defined conditions of temperature and elongation rate. Newtonian behaviour asphalts (sol type) characterized by lower asphaltene contents have higher ductility. The ductility correlates with the colloidal Instability Index (I_c) defined in section 5.1 (Figure 8). The results in Tables 4 and 5 show that the ductility decreases with increasing I_c. However, it appears that factors other than I_c such as the penetration would also effect the

ductility. For example Peace River and Tia Juana Medium asphalts which have an I_c of 0.46 have a ductilities at 25°C of of 83 and 120 cm respectively. However, considering the poor repeatability of the ductility test, these values are not significantly different. Corbett (3) has reported that naphthene-aromatics do not affect the ductility as much as polar aromatics. This is consistent with our results although blending the naphthene-aromatics with Peace River residue increase the ductility from 83 to 120 cm. Air blowing or blending saturates into asphalt decrease the ductility significantly. This is also reflected by an increase of the I_c value.

6. CONCLUSIONS

Blending a given compound-type into asphalt affects its overall composition. The temperature susceptibility of asphalt cement measured by the Penetration Index correlates well with the asphaltenes/(wax + polar aromatics) ratio. Air blowing or blending saturates into asphalt provide a way to reduce the low temperature stiffness. This reduction in stiffness is reflected by an increase of the Penetration Index.

Blending naphthene-aromatics or propane precipitated asphalt (PPA) with asphalt does not change its Pen-Vis Number. Also, air blowing Peace River residue does not improve its PVN. The saturates fraction used in this study improves the PVN of Cold Lake asphalt.

The glass transition temperature is one of the most important properties of asphalt cement relating to the low temperature behaviour of asphalts. It is correlated with the polar aromatics for similar penetration asphalts.

The ductility directionally decreases with increasing I_c. Asphalt with low T_g, low stiffness at -20°C and high PI also have lower ductility.

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TABLES

TABLE 1

PROPERTIES OF COLD LAKE 150/200 AND DEASPHALTED FRACTIONS

Cold Lake 150/200 Asphalt	
Properties	
Penetration at 25°C (100/5)	152
Density at 15°C, kg/m^3	1.0326
Viscosity at 135°C, cSt	276
Deasphalted Oil (DAO)	
Yield, LV%	39.0
Density at 15°C, kg/L	0.9614
Refractive Index at 67°C	1.5164
Viscosity at 100°C, cSt	29
Propane Precipitated Asphalt (PPA)	
Yield, LV%	61.0
Density at 15°C, kg/L	1.0783
Composition (ASTM D4124)	
Saturates, wt%	3.5
Naphthene-Aromatics, wt%	27.4
Polar Aromatics, wt%	40.2
Asphaltenes, wt%	28.9

TABLE 2

ASPHALT SAMPLES USED IN THIS STUDY

Samples (1)	Penetration at 25°C (100/5)
1. Air Blown Peace River	161
2. Peace River	189
3. Cold Lake	157
4. Visbroken Cold Lake	150
5. 90 wt% Visbroken Cold Lake (90 Pen) 10 wt% Naphthene-Aromatics	177
6. 88 wt% Peace River (61 Pen) 12 wt% Naphthene-Aromatics	184
7. 90 wt% Peace River (313 Pen) 10 wt% Propane Precipitated Asphalt (PPA)	165
8. 87 wt% Cold Lake (47 Pen) 13 wt% Saturates	185

(1) Except for sample 1 all asphalts are vacuum residues.

TABLE 3

EFFECT OF BLENDING SATURATES, NAPHTHENE-AROMATICS AND PROPANE PRECIPITATED ASPHALT ON THE COMPOUND-TYPE DISTRIBUTION (WT%)

Sample	Saturates	Naphthene-Aromatics	Polar Aromatics	Asphaltenes
Peace River	22.0	39.4	29.0	9.6
Peace River + 12% NA Found	17.6	42.7	30.2	9.5
Calculated	19.4	46.7	25.5	8.4
Peace River +10% PPA Found	21.9	39.6	27.3	11.2
Calculated	20.2	38.2	30.1	11.5
Cold Lake	11.5	34.0	39.6	14.9
Cold Lake +13% SATS Found	21.0	33.9	27.8	17.3
Calculated	23.0	29.6	34.4	13.0
Visbroken Cold Lake	12.5	39.6	24.2	23.7
Visbroken Cold Lake + 10% NA Found	12.1	44.0	23.7	20.2
Calculated	11.3	45.6	21.8	21.3

TABLE 4

PROPERTIES OF 150/200 PENETRATION ASPHALTS

Sample	Peace River	Peace River + NA	Peace River + PPA	Air Blown Peace River	Cold Lake	Cold Lake + Sat	Visbroken Cold Lake	Visbroken Cold Lake + NA
Softening Point, C	41.4	41.0	43.8	43.0	40.0	37.2	38.5	36.3
Penetration at 30 C (100/5)	328	306	274	283	257	295	227	283
25 C (100/5)	189	184	165	161	157	185	150	177
10 C (100/5)	29	28	28	40	32	42	32	38
4 C (100/5)	13.5	13.5	14.8	22	15.5	22	18.5	22
4 C (200/60)	48	46	46	65	59	77	59	70
0 C (200/60)	28	29	29	43	37	49	38	47
Penetration Index	-1.92	-1.94	-1.50	-0.13	-0.98	-0.54	-0.61	-0.62
Penetration Ratio (1)	25.4	25.0	27.9	40.4	37.6	41.6	39.3	39.5
Viscosity at 60 C, Poise	252	319	286	272	845	686	716	524
100 C, cSt	781	935	846	752	1897	1701	1290	1058
135 C, cSt	130	151	140	127	255	245	155	145
Pen-Vis Number	-1.34	-1.10	-1.35	-1.54	-0.39	-0.25	-1.28	-1.21
Ductility at 4 C (1 cm/min), cm	>50	>50	>50	12	>50	>50	>50	>50
25 C (5 cm/min), cm	83	120	91	46	>150	124	111	89
Wax, wt% (DSC)	3.3	3.3	3.3	3.3	0	0	0	0
Glass Transition Temperature, C	-36	-34	-37	-42	-27	-35	-33	-33
Composition (ASTM D4124)								
Saturates, wt%	22.0	17.6	21.9	26.2	11.5	21.0	12.5	12.1
Naphthene-Aromatics, wt%	39.4	42.7	39.6	35.5	34.0	33.9	39.6	44.0
Polar Aromatics, wt%	29.0	30.2	27.3	24.1	39.6	27.8	24.2	23.7
Asphaltenes, wt%	9.6	9.5	11.2	14.2	14.9	17.3	23.7	20.2
I_c	0.46	0.37	0.49	0.68	0.36	0.62	0.57	0.48

(1) 100 [4 C (200/60)/25 C (100/5)]

TABLE 5

COMPOSITIONAL ANALYSIS OF ASPHALTS FROM OTHER CRUDE SOURCES, WT%
ASTM D4124

Sample	Wax (1)	Saturates	Naphthene Aromatics	Polar Aromatics	Asphaltenes	PI	PVN	T_g	Ductility 25 C, cm	I_c
Pembina	7.1	13.4	39.5	35.7	4.3	-2.6	-0.69	-	>150	0.27
Tia Juana Medium	2.4	14.1	37.3	31.3	14.9	-1.0	-0.36	-37	120	0.43
Arabian Light	3.5	9.8	49.6	30.1	7.0	-1.8	-0.32	-	>150	0.23
Kirkuk	3.1	11.2	39.4	36.1	10.2	-2.1	-0.67	-	127	0.30
Kuwait	2.2	10.5	39.1	40.0	11.7	-2.0	-0.20	-	>150	0.30
Cold Lake	0.0	11.5	34.0	39.6	14.9	-1.0	-0.39	-27	>150	0.36
Cold Lake + 5% Wax (2)	5.0	11.1	32.0	37.5	14.4	-1.5	-0.72	-30	>150	0.39
Cold Lake + 10% Wax (2)	10.0	10.4	29.9	35.8	13.9	-1.7	-1.16	-31	79	0.42

(1) Wax content subtracted equally from saturates and naphthene aromatics.
(2) Samples prepared by blending wax with Cold Lake vacuum residue (Ref. 3).

TABLE 6

CREEP RESISTANCE AND DUCTILITY OF
150/200 PENETRATION ASPHALT VERSUS
COLLOIDAL INSTABILITY INDEX AND PENETRATION INDEX

Sample	Stiffness at 500s -20°C, MPa (1)	Ductility 25°C, cm	I_c (2)	PI
Peace River	29.6	83	0.46	-1.92
Peace River +12% N-A	26.9	120	0.37	-1.94
Peace River + 10% PPA	30.8	91	0.49	-1.50
Peace River Air Blown	21.1	46	0.68	-0.13
Cold Lake	14.5	>150	0.36	-0.98
Cold Lake + 13% Sats	4.0	124	0.62	-0.54
Visbroken Cold Lake	11.9	111	0.57	-0.61
Visbroken Cold Lake + 10% N-A	8.3	89	0.48	-0.62

(1) Vander Poel stiffness modulus at 500S loading time ($S(t) = 3/J(t)$)

(2) $I_c = \frac{\text{saturates + asphaltenes}}{\text{naphthene-aromatics + polar aromatics}}$

TABLE 7

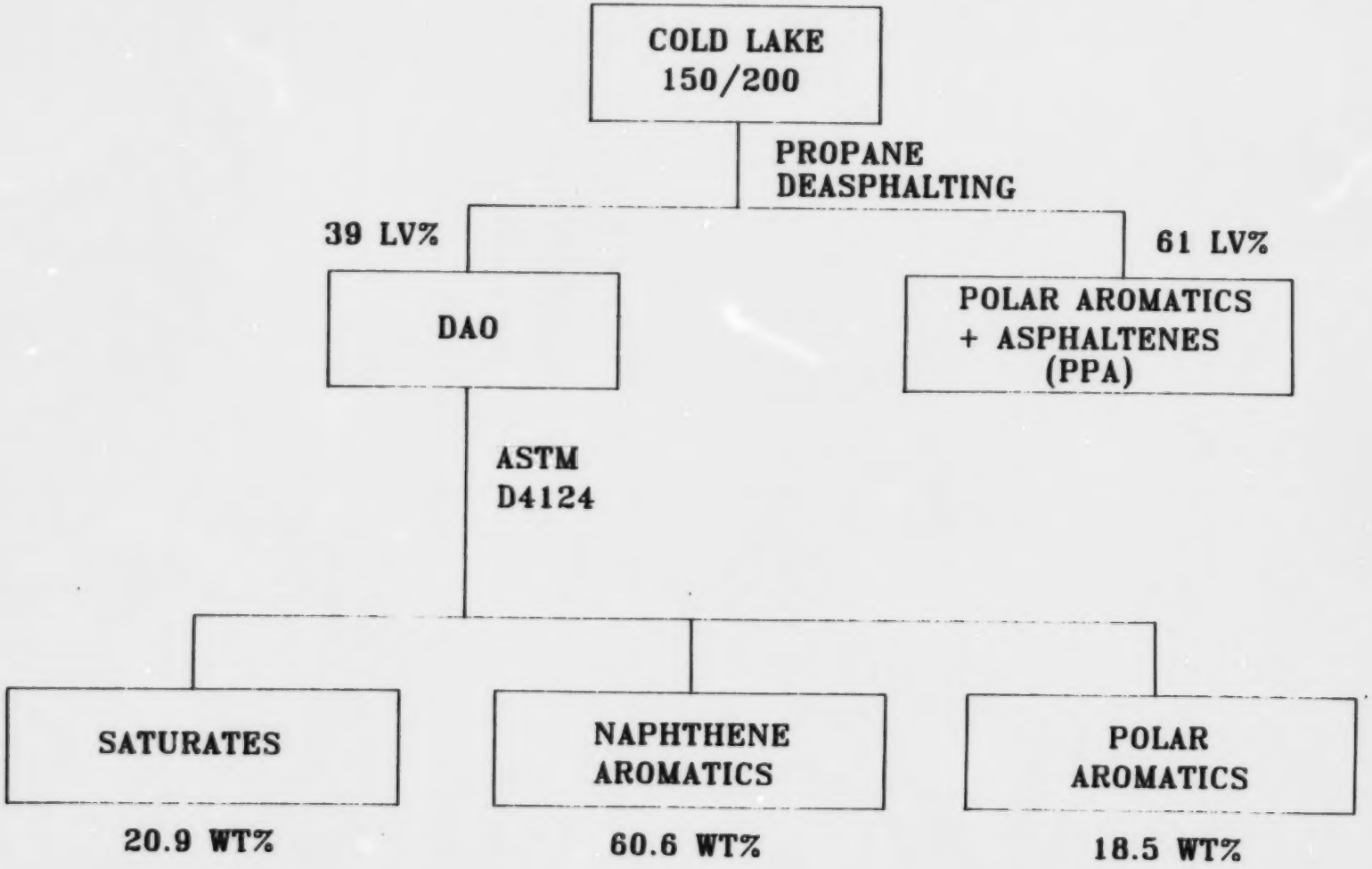
VISCOSITY OF ASPHALT AT 60°C

Sample	Cone and Plate at 0.1 s^{1} Shear Rate, Poise	ASTM D2171, Poise
Peace River	434	252
Peace River + NA	440	319
Peace River + PPA	447	286
Air Blown Peace River	431	272
Cold Lake	1245	845
Cold Lake + Sat	1079	686
Visbroken Cold Lake	1264	716
Visbroken Cold Lake + NA	785	524

FIGURES

FIGURE 1

BLENDING COMPONENT SEPARATION SCHEME



MAP00288

FIGURE 2

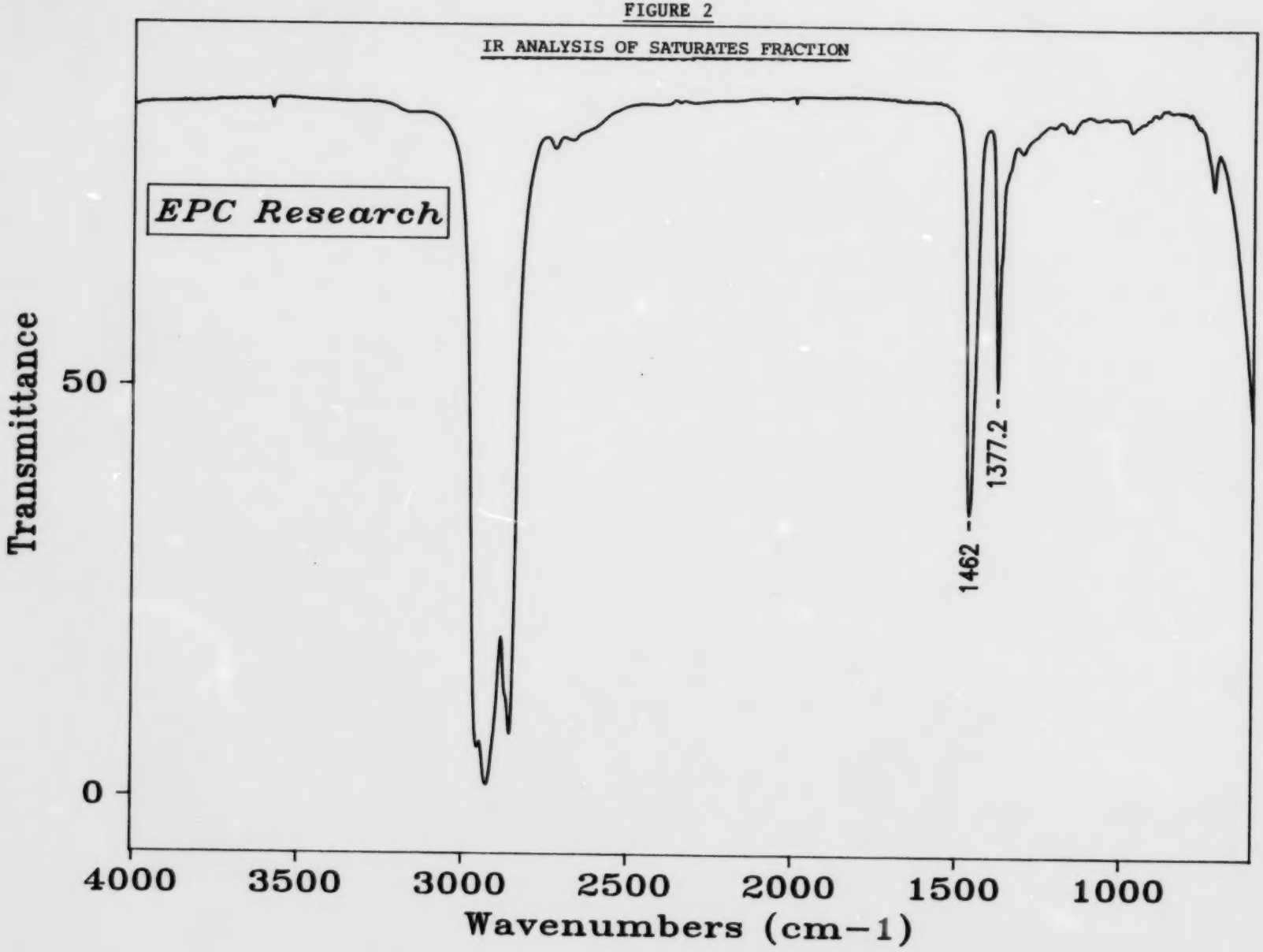

IR ANALYSIS OF SATURATES FRACTION
EPC Research
Transmittance
50
0
1462
1377.2
4000
3500
3000
2500
2000
1500
1000
Wavenumbers (cm-1)

FIGURE 3

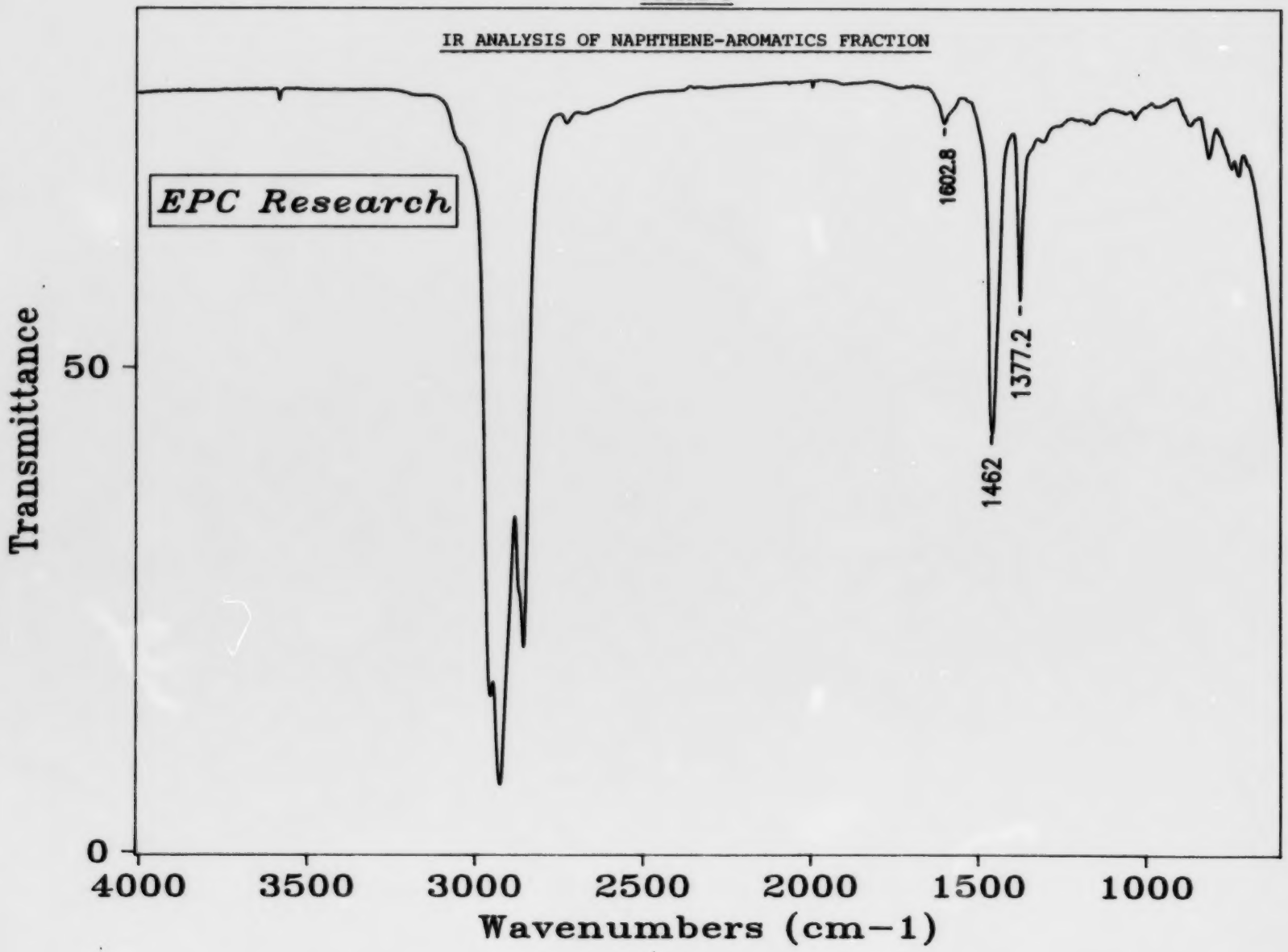
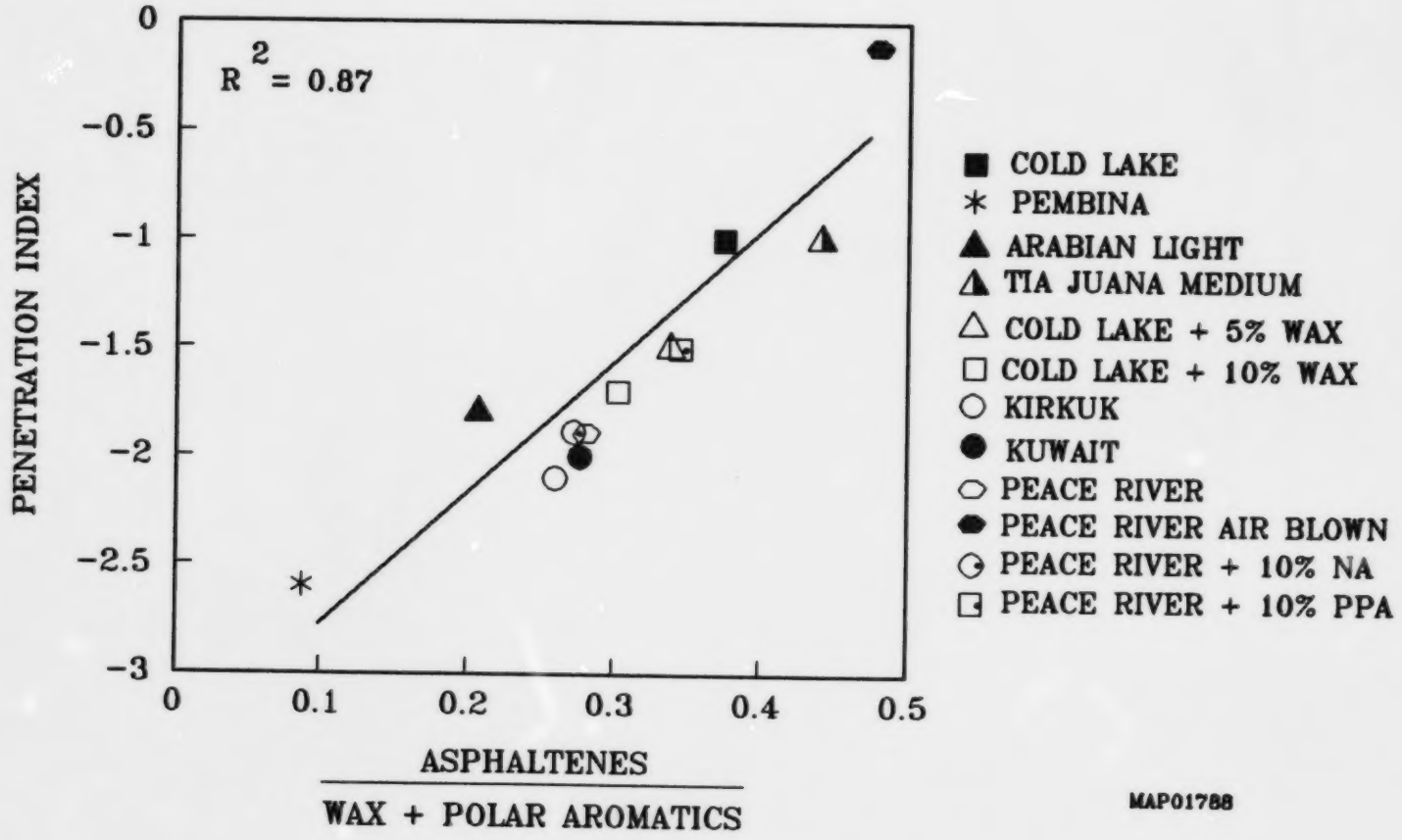

IR ANALYSIS OF NAPHTHENE-AROMATICS FRACTION
EPC Research
Transmittance
50
0
1602.8
1462
1377.2
4000
3500
3000
2500
2000
1500
1000
Wavenumbers (cm-1)

FIGURE 4

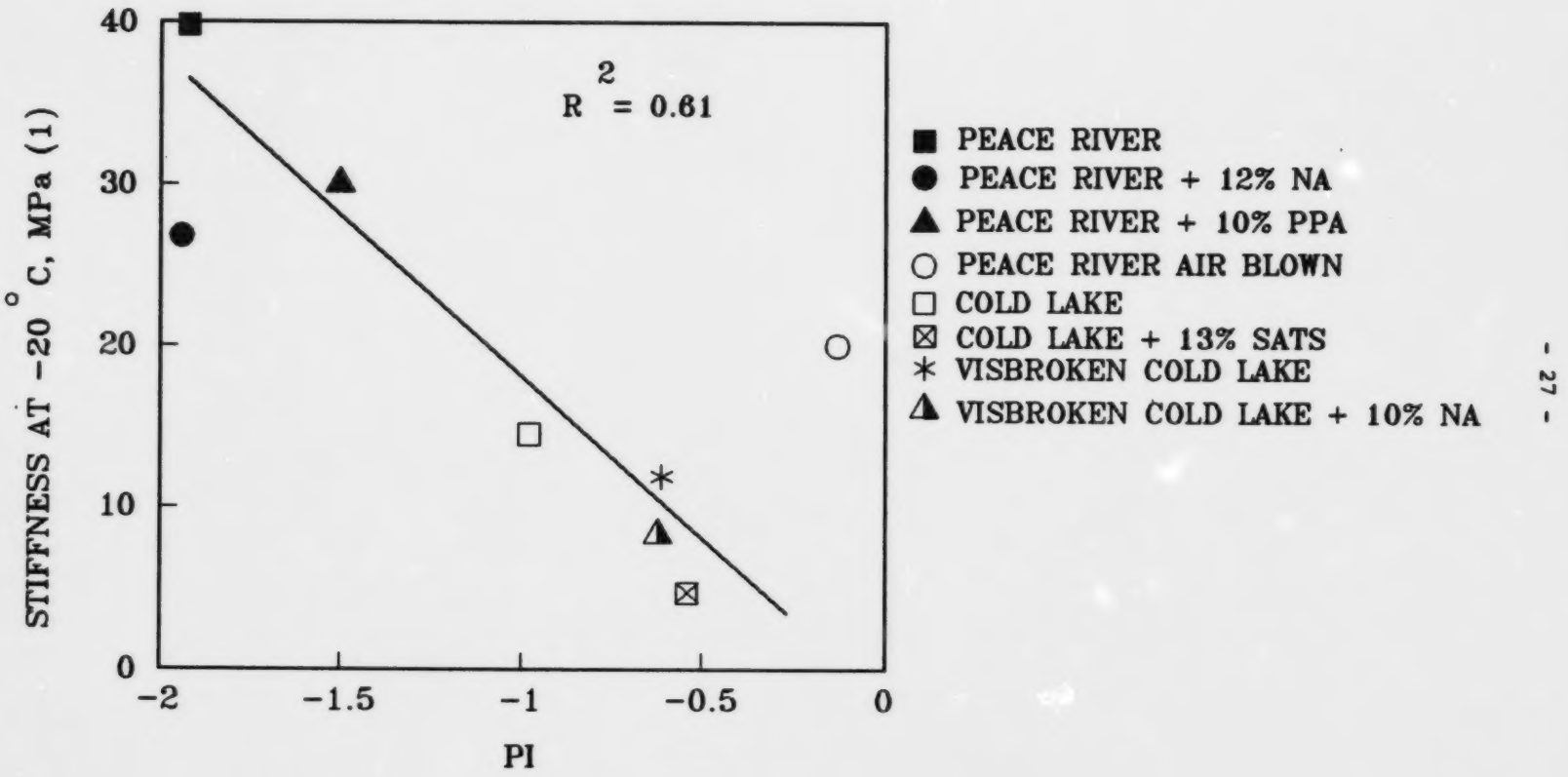
PENETRATION INDEX/COMPOSITION RELATIONSHIP



MAP01788

FIGURE 5

STIFFNESS MODULUS VERSUS PENETRATION INDEX



(1) VAN DER POEL STIFFNESS MODULUS AT 500 S LOADING TIME. S(t)=3/J(t)

MAP01488

FIGURE 6

DSC THERMOGRAM OF COLD LAKE ASPHALT

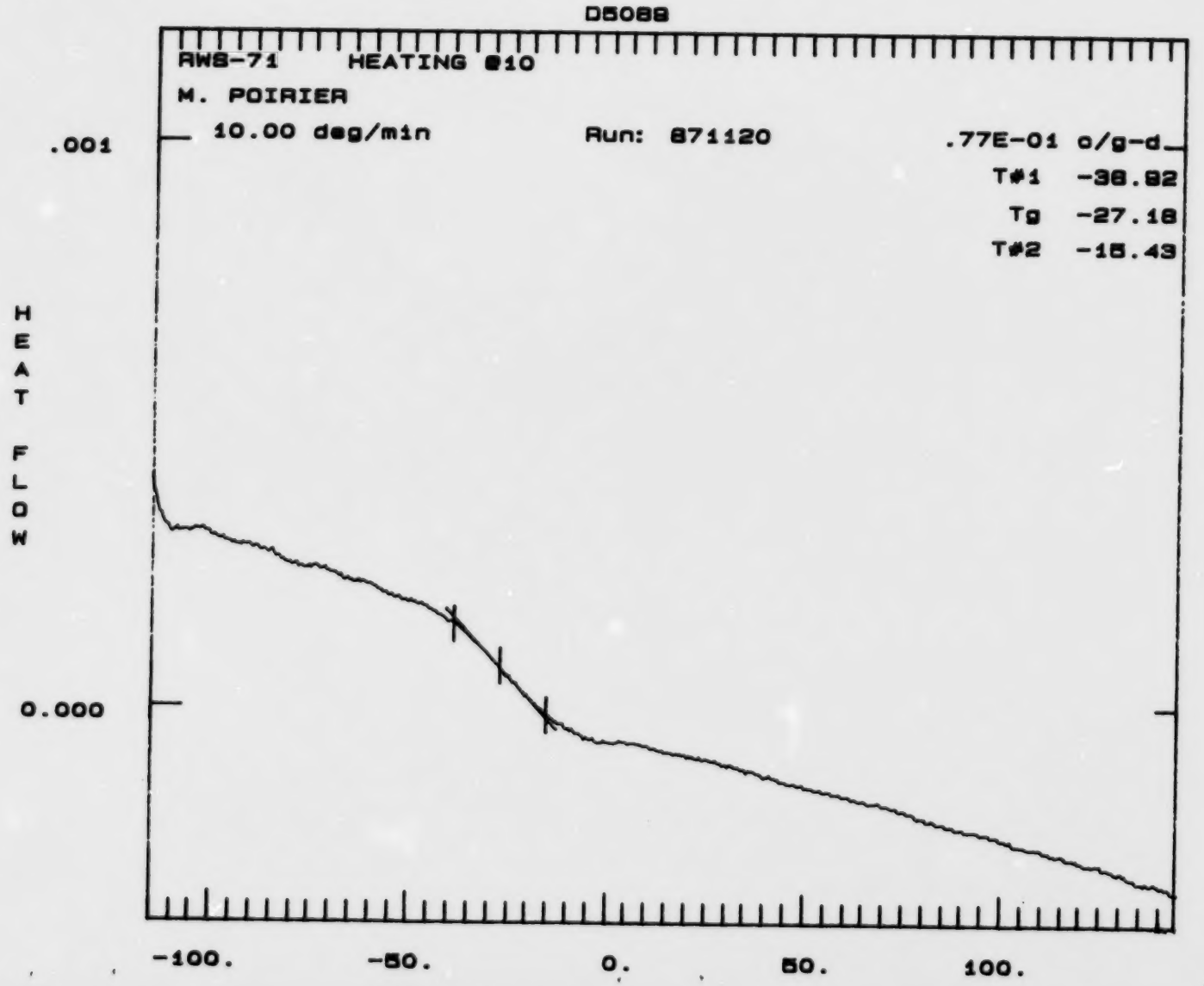
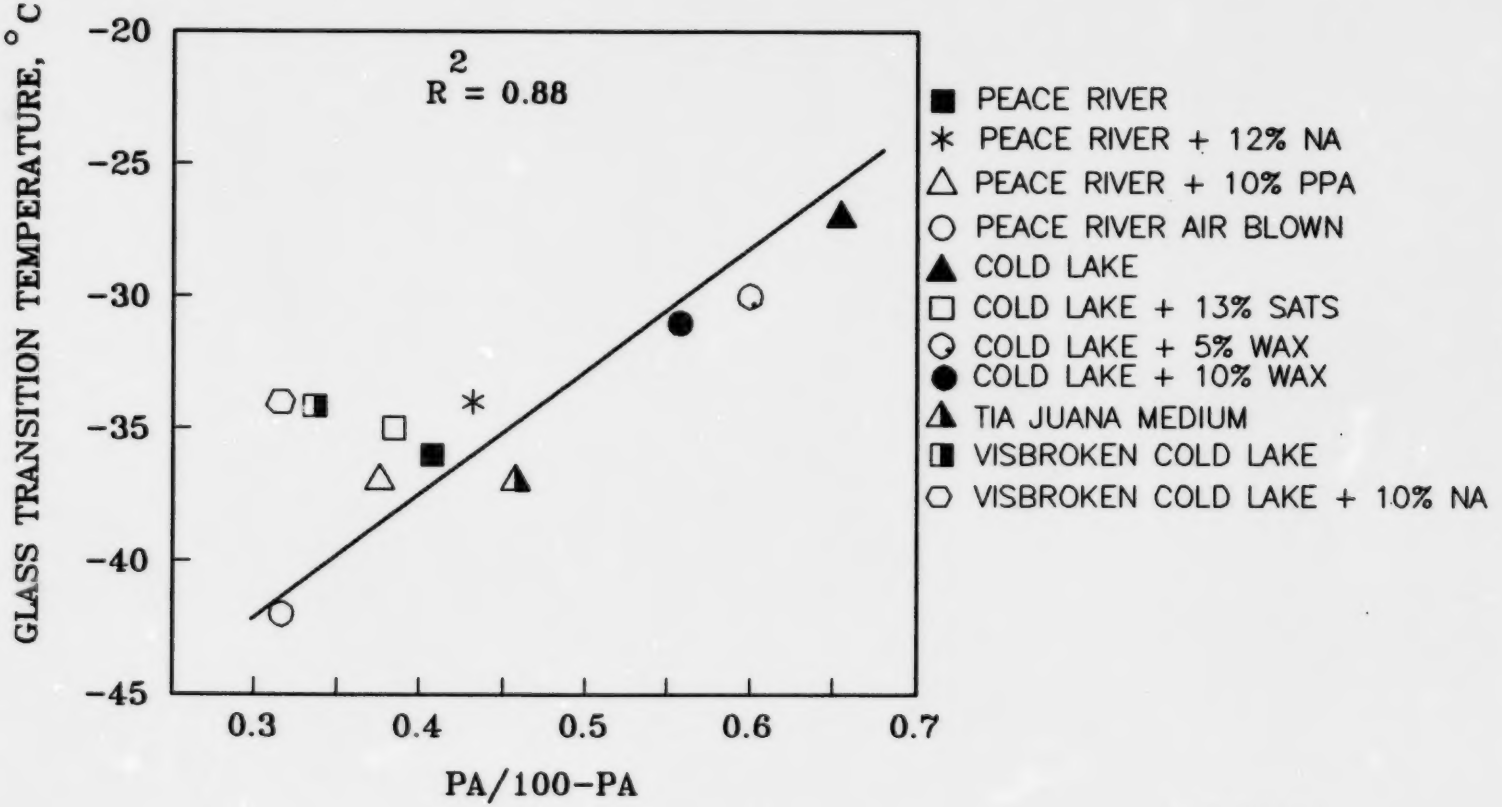


FIGURE 7

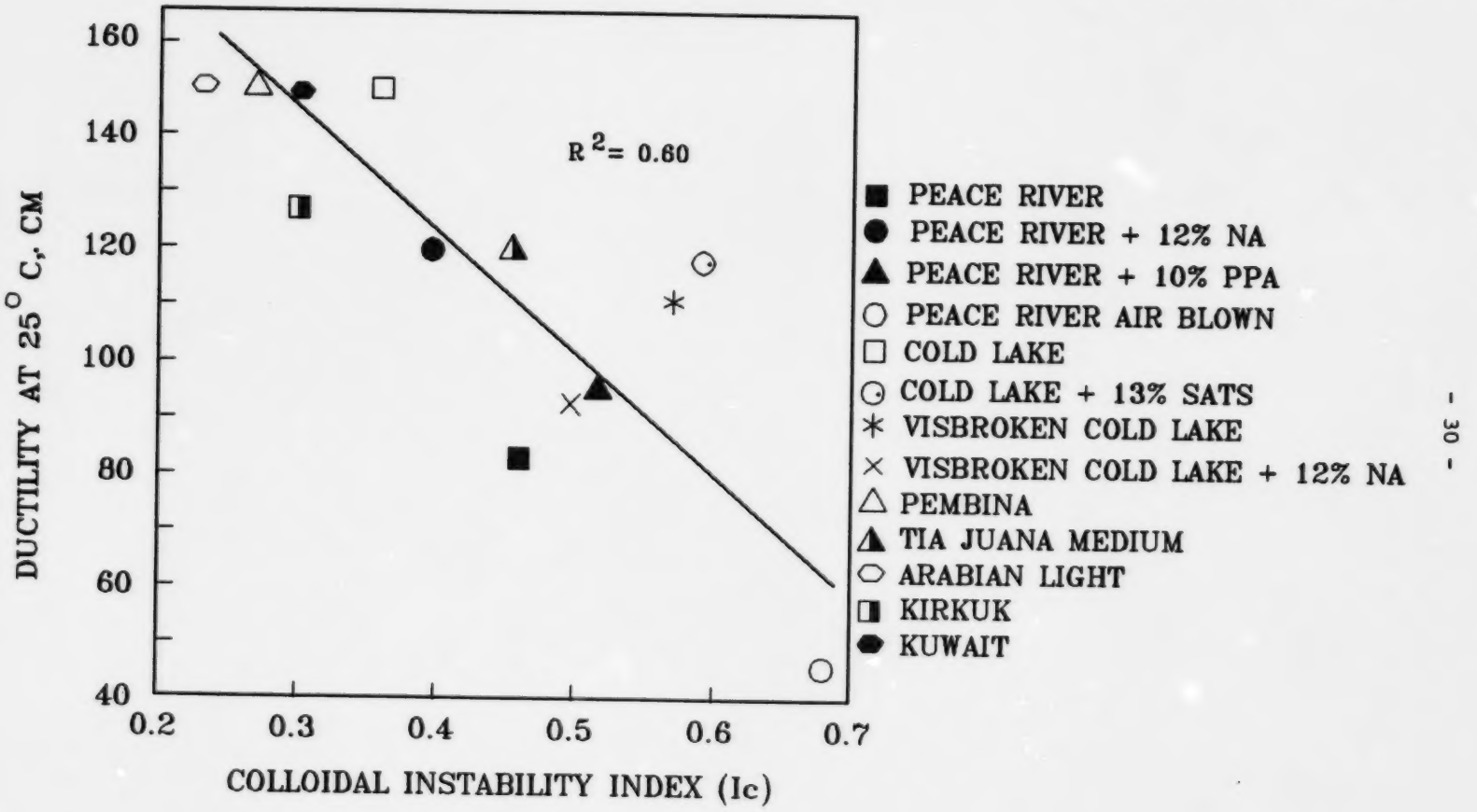
GLASS TRANSITION TEMPERATURE VERSUS COMPOSITION



MAP01588

FIGURE 8

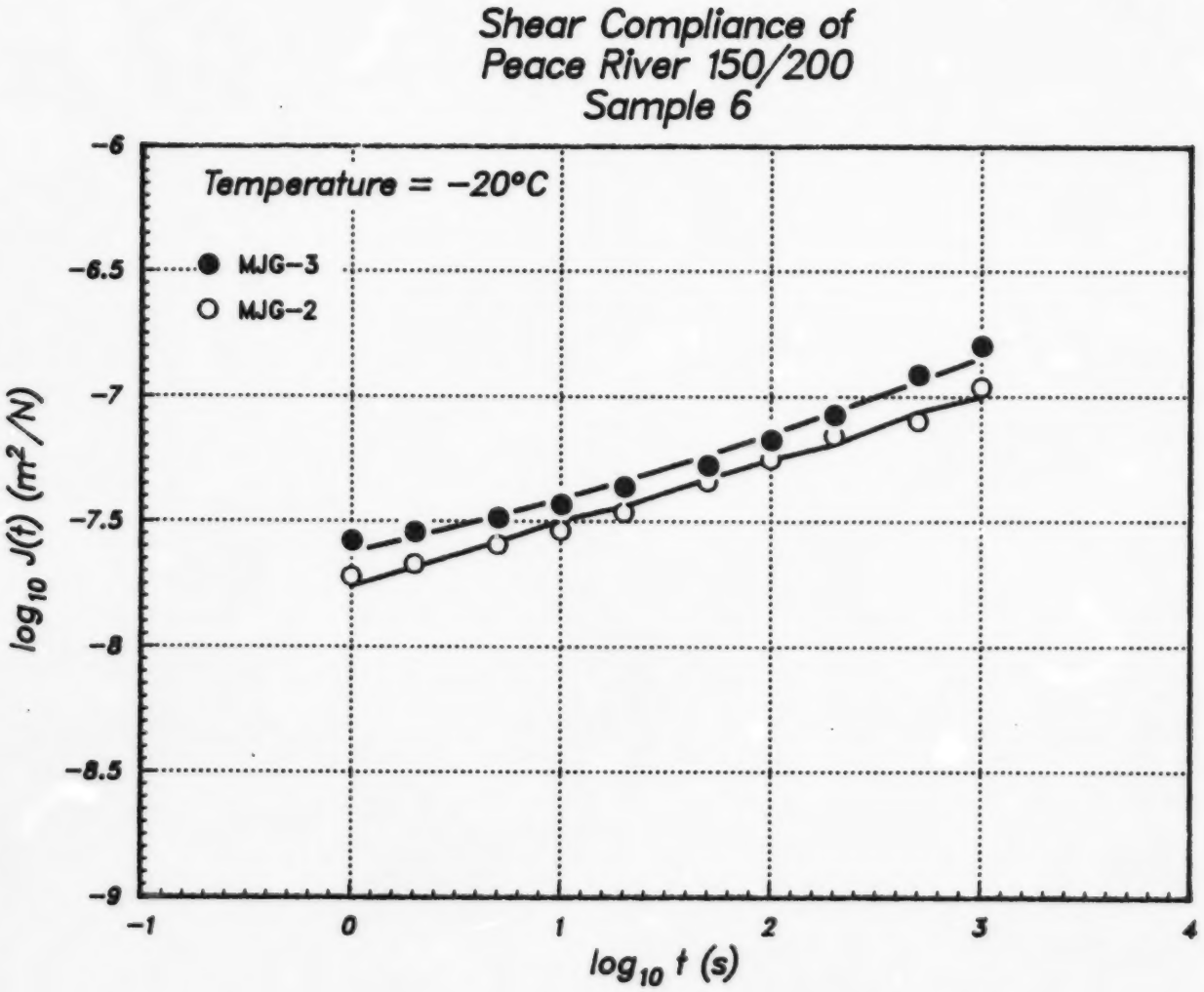
DUCTILITY VERSUS COLLOIDAL INSTABILITY INDEX RELATIONSHIP

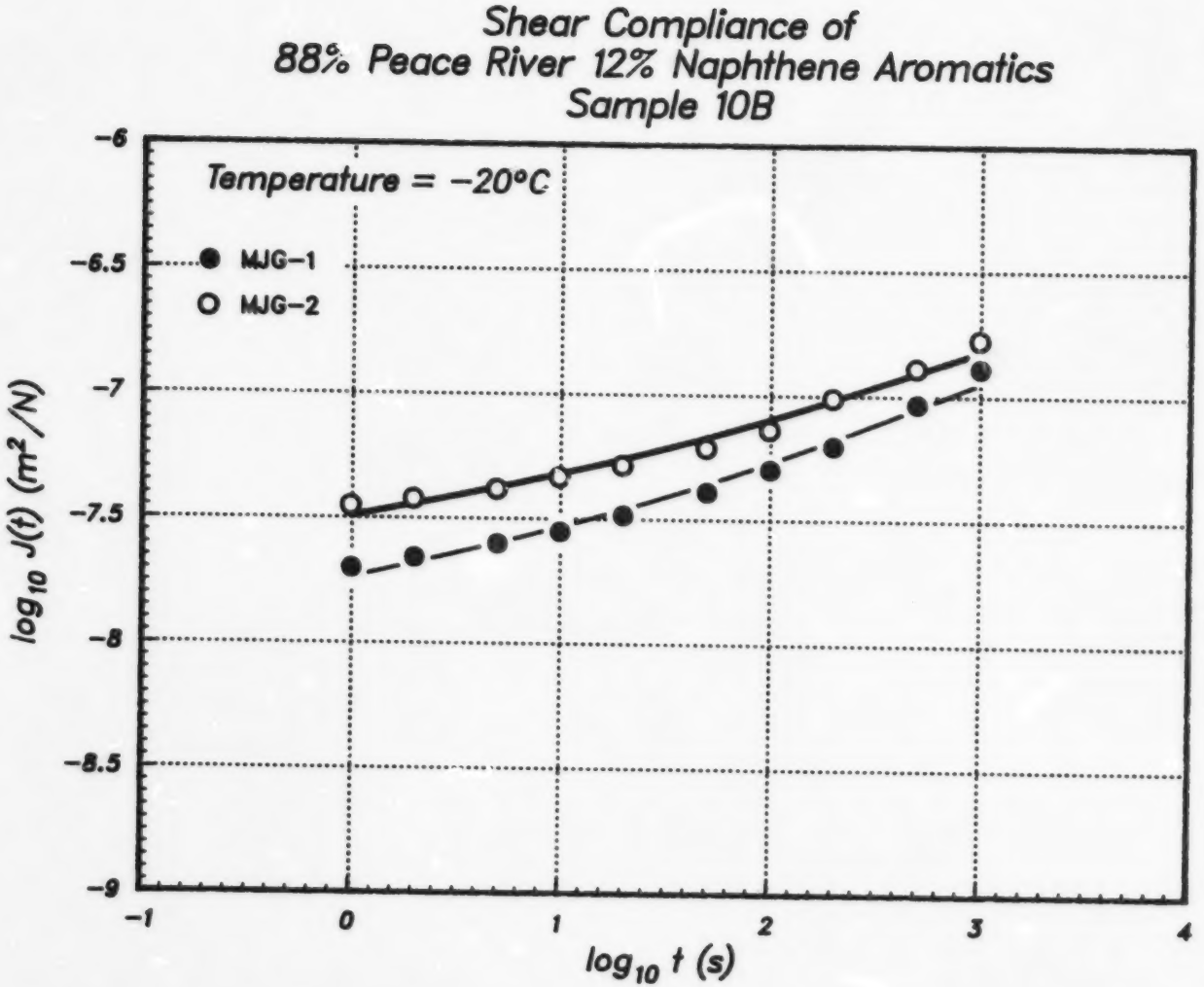


MAP01688

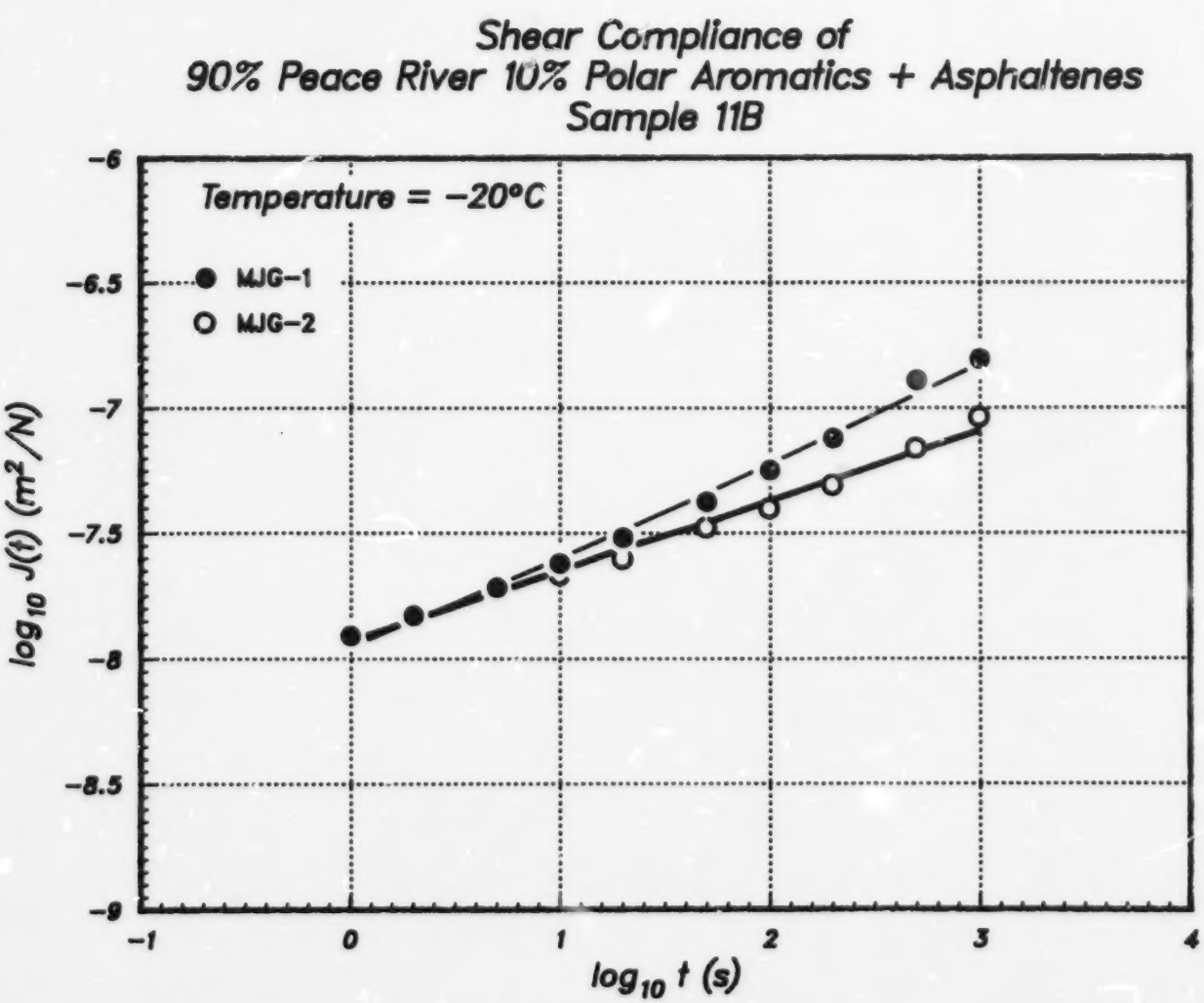
APPENDIX

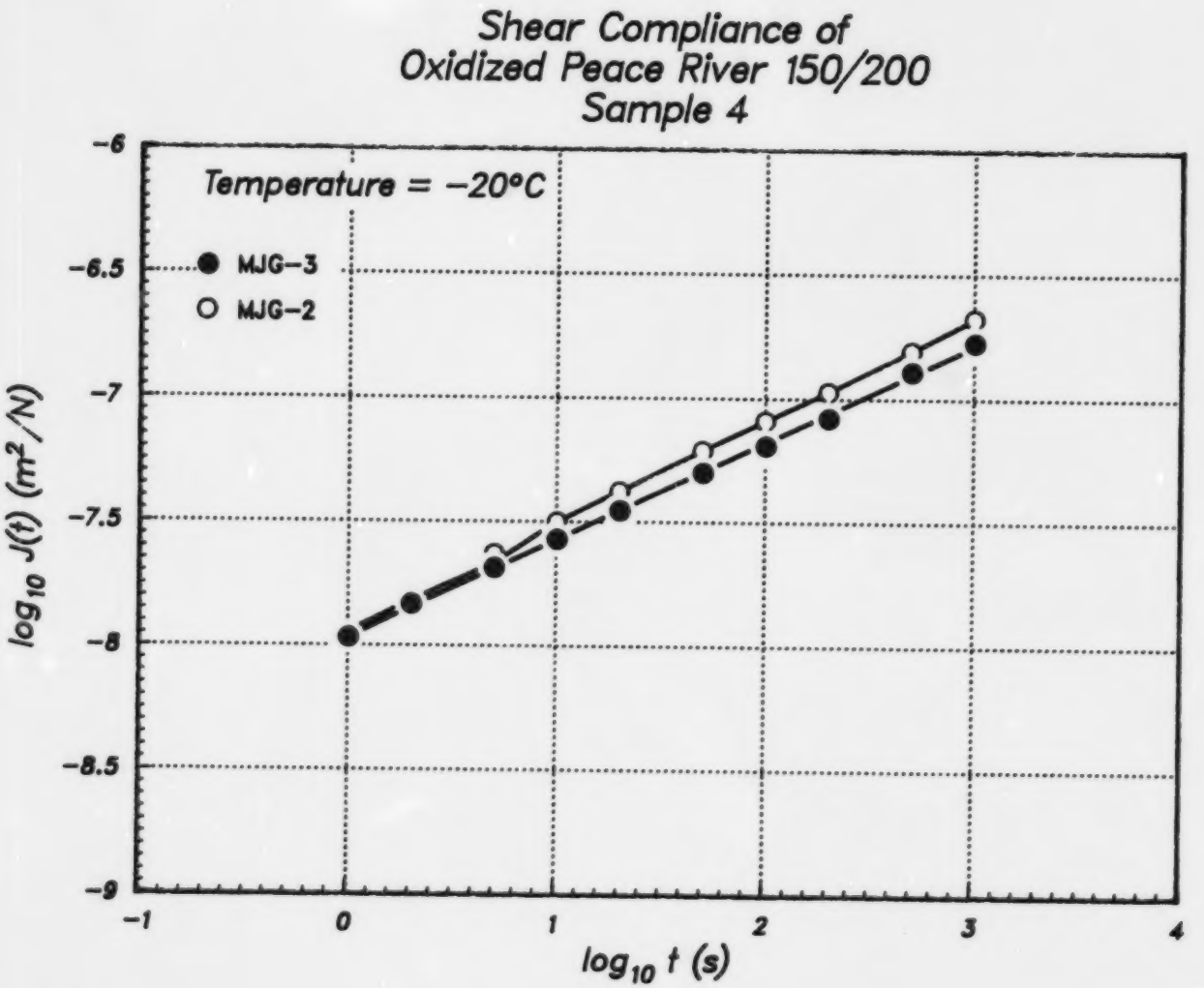
APPENDIX 1


Shear Compliance of
Peace River 150/200
Sample 6
Temperature = −20°C
MJG−3
MJG−2
−6
−6.5
−7
−7.5
−8
−8.5
−9
−1
0
1
2
3
4
log10 J(t) (m²/N)
log10 t (s)

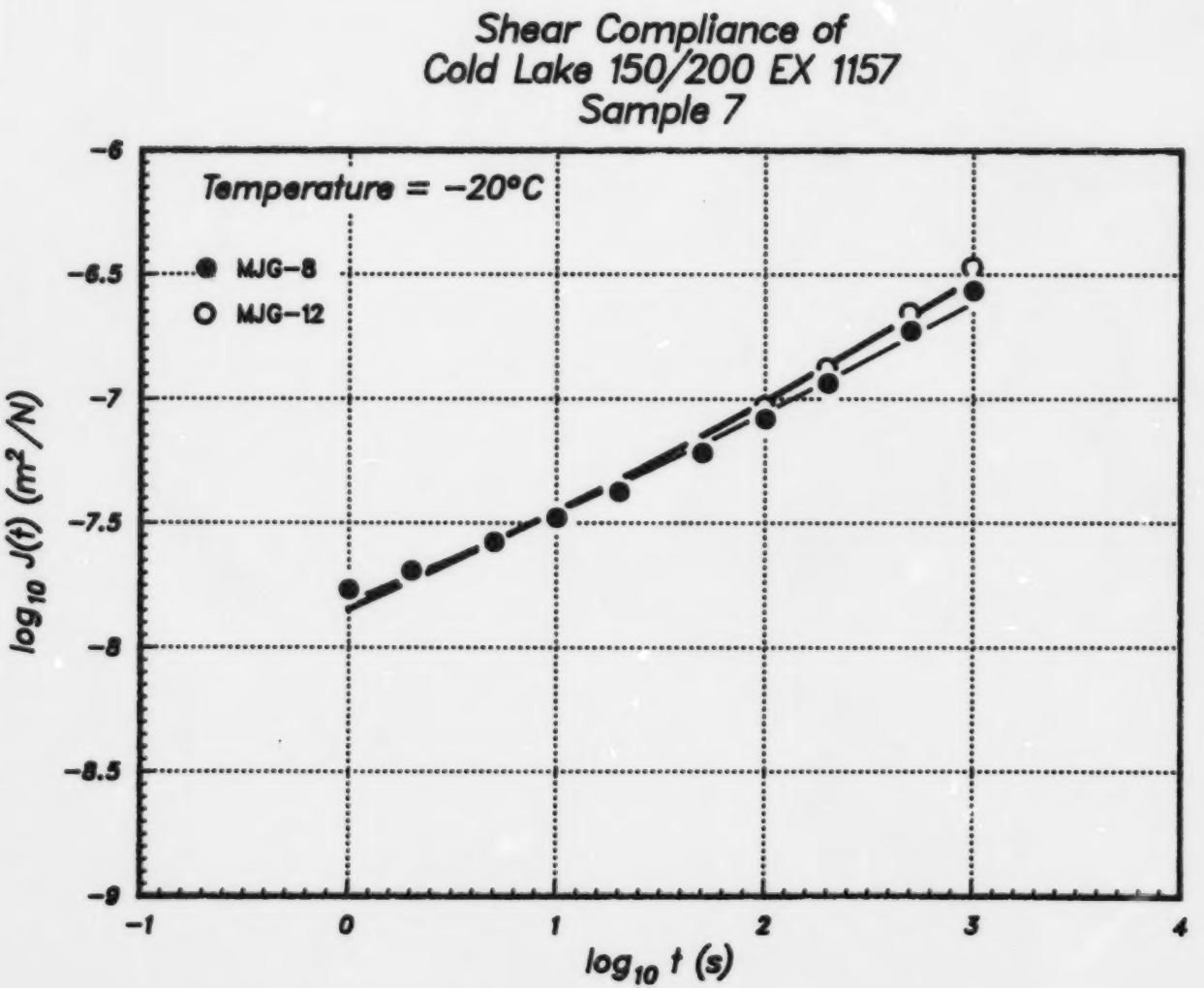

Shear Compliance of
88% Peace River 12% Naphthene Aromatics
Sample 10B
Temperature = −20°C
MJG−1
MJG−2
−6
−6.5
−7
−7.5
−8
−8.5
−9
−1
0
1
2
3
4
log10 J(t) (m²/N)
log10 t (s)

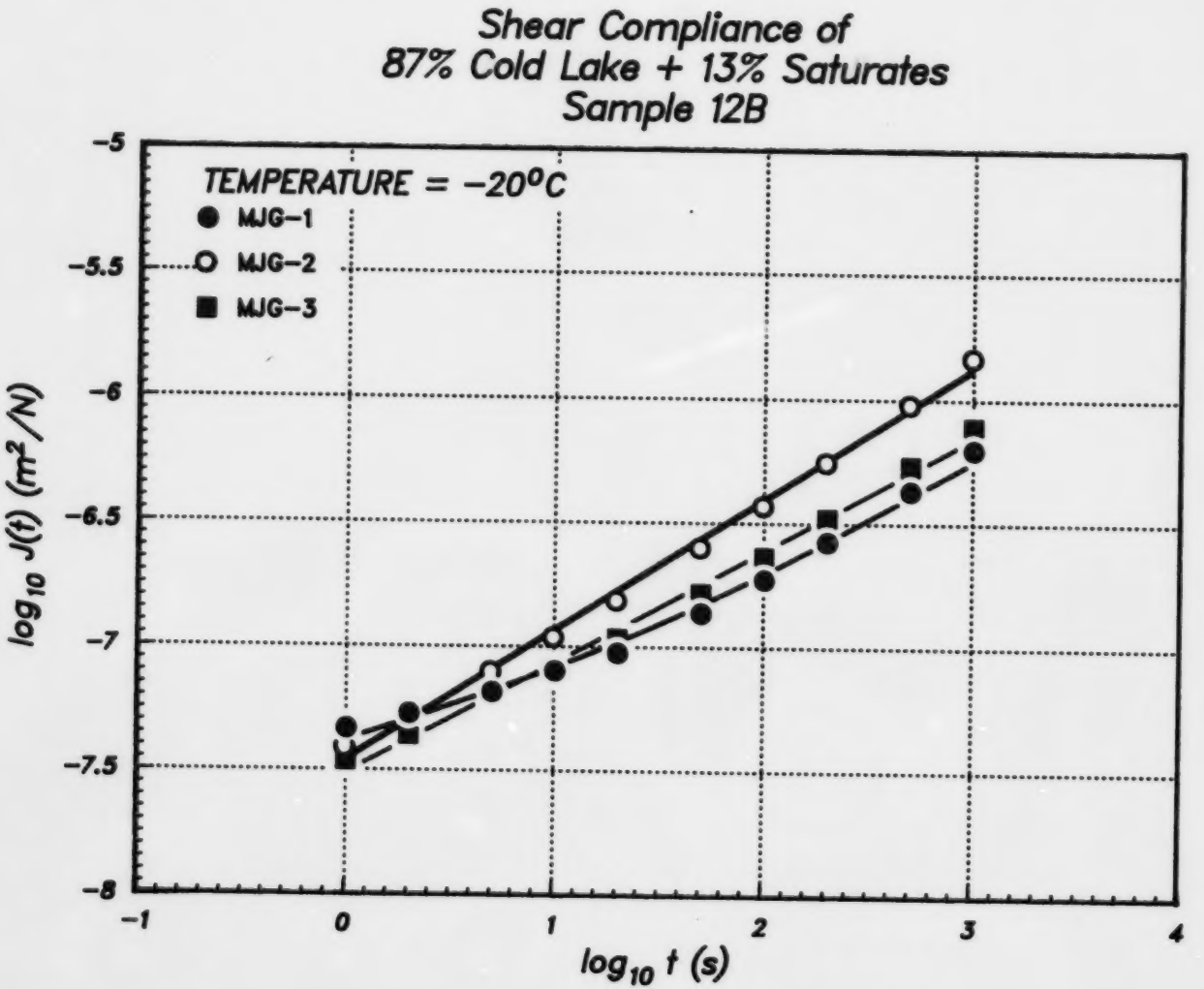
APPENDIX 3


Shear Compliance of
90% Peace River 10% Polar Aromatics + Asphaltenes
Sample 11B
Temperature = −20°C
MJG−1
MJG−2
log10 J(t) (m²/N)
log10 t (s)
−6
−6.5
−7
−7.5
−8
−8.5
−9
−1
0
1
2
3
4

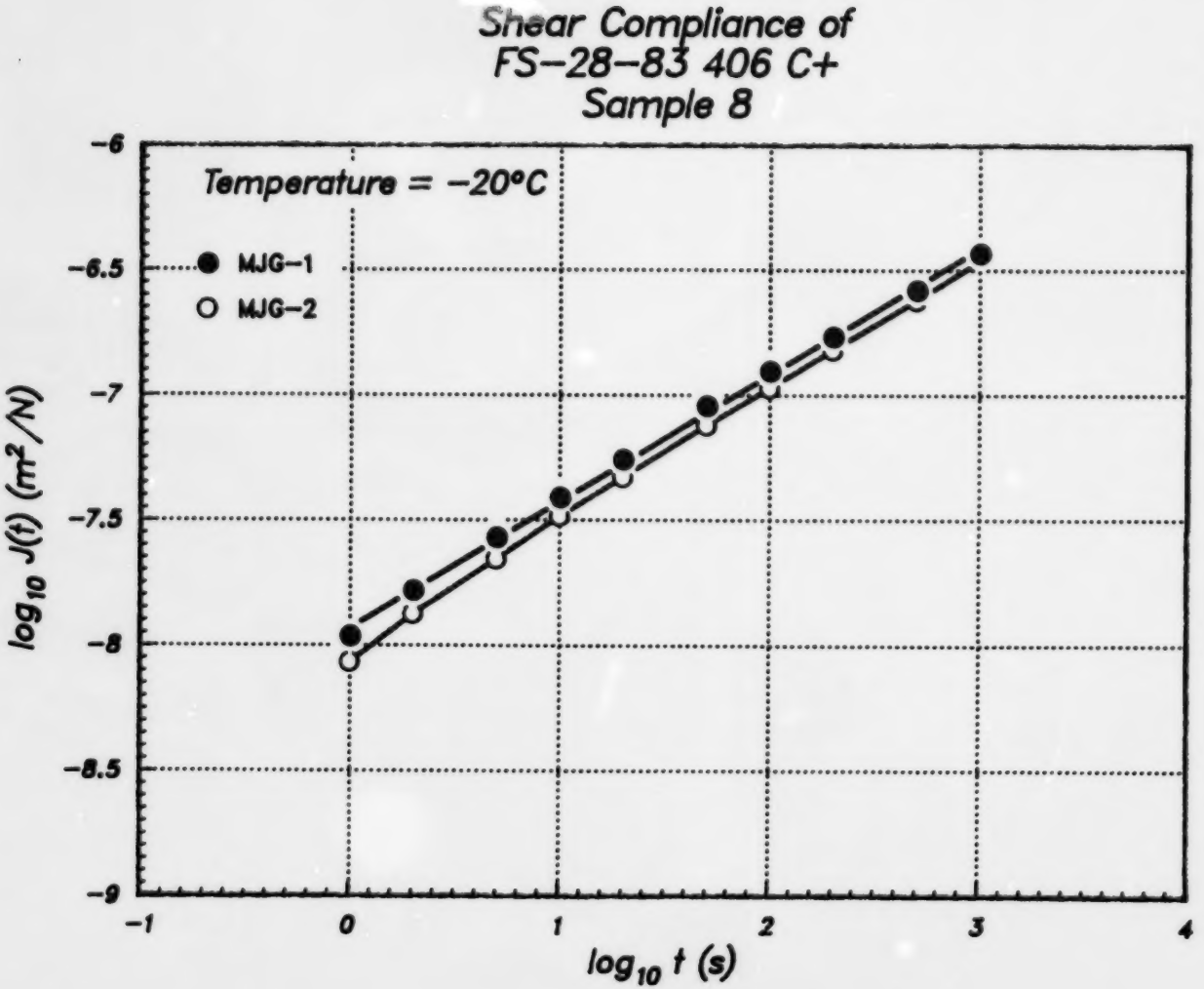

Shear Compliance of
Oxidized Peace River 150/200
Sample 4
Temperature = −20°C
MJG−3
MJG−2
−6
−6.5
−7
−7.5
−8
−8.5
−9
log10 J(t) (m²/N)
−1
0
1
2
3
4
log10 t (s)

APPENDIX 5

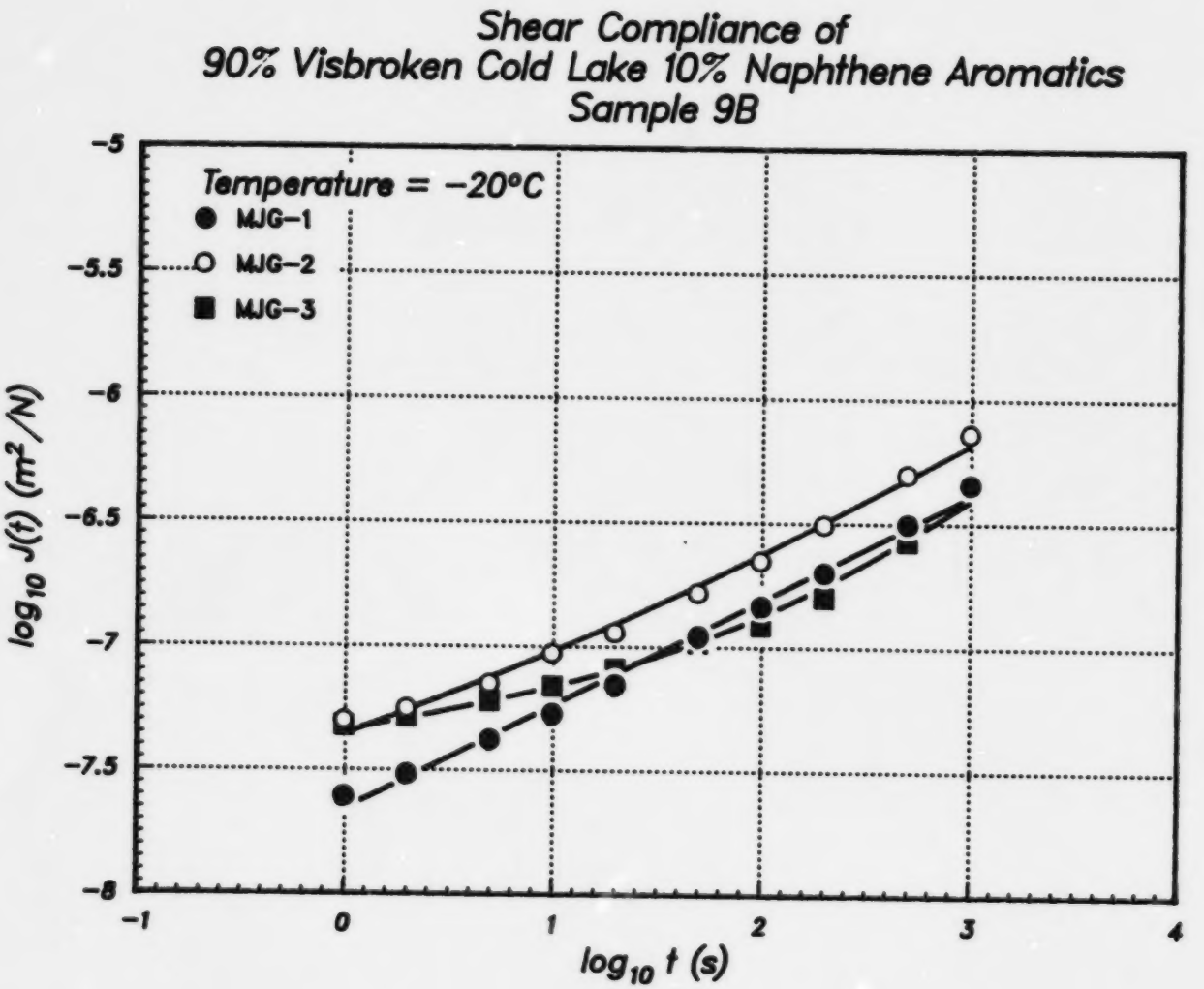

Shear Compliance of
Cold Lake 150/200 EX 1157
Sample 7
Temperature = −20°C
MJG−8
MJG−12
−6
−6.5
−7
−7.5
−8
−8.5
−9
−1
0
1
2
3
4
log10 J(t) (m²/N)
log10 t (s)


Shear Compliance of
87% Cold Lake + 13% Saturates
Sample 12B
TEMPERATURE = −20°C
MJG−1
MJG−2
MJG−3
−5
−5.5
−6
−6.5
−7
−7.5
−8
−1
0
1
2
3
4
log10 J(t) (m²/N)
log10 t (s)

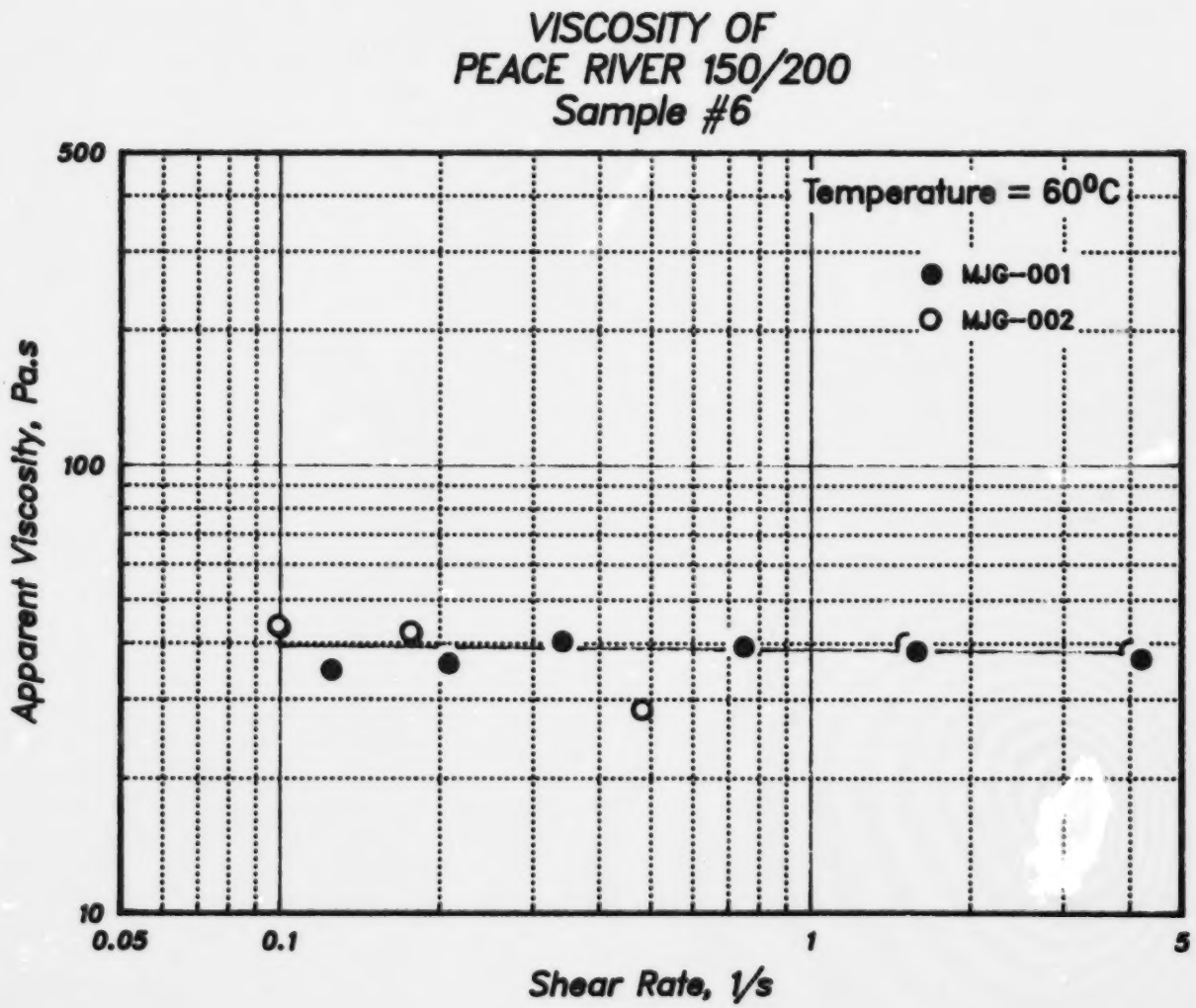
APPENDIX 7

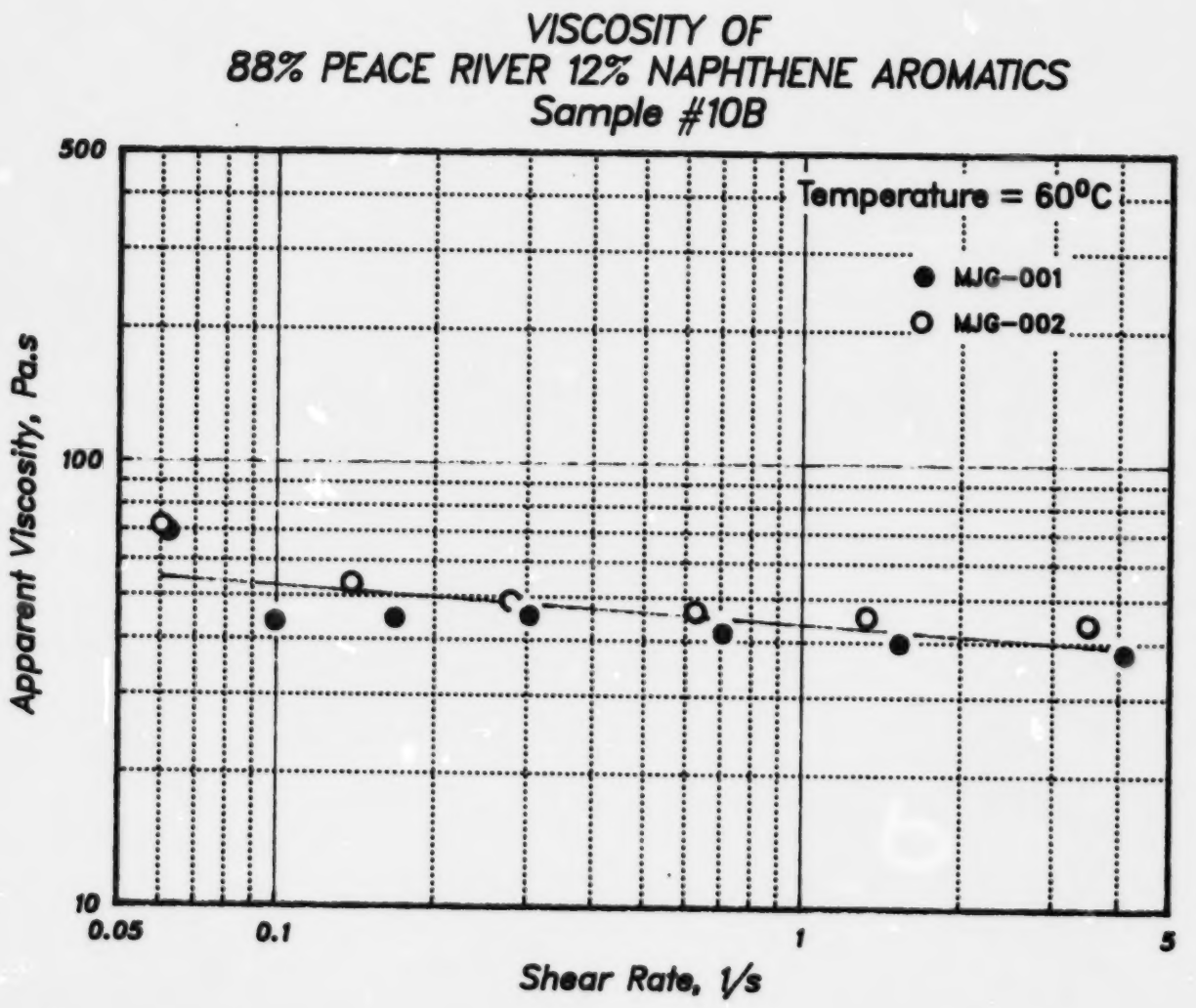

Shear Compliance of
FS–28–83 406 C+
Sample 8
Temperature = –20°C
MJG–1
MJG–2
log10 J(t) (m²/N)
log10 t (s)
–6
–6.5
–7
–7.5
–8
–8.5
–9
–1
0
1
2
3
4

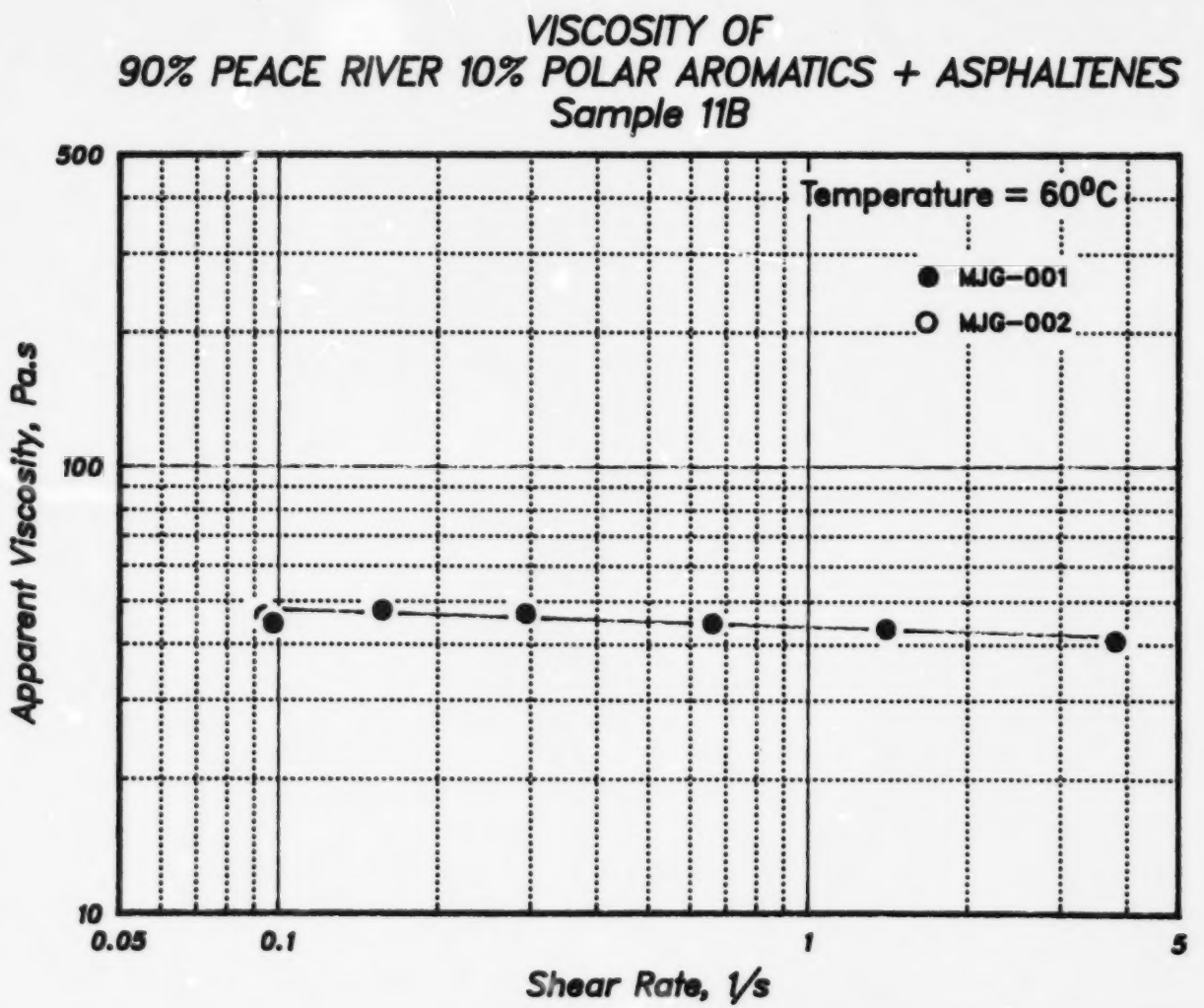
APPENDIX 8

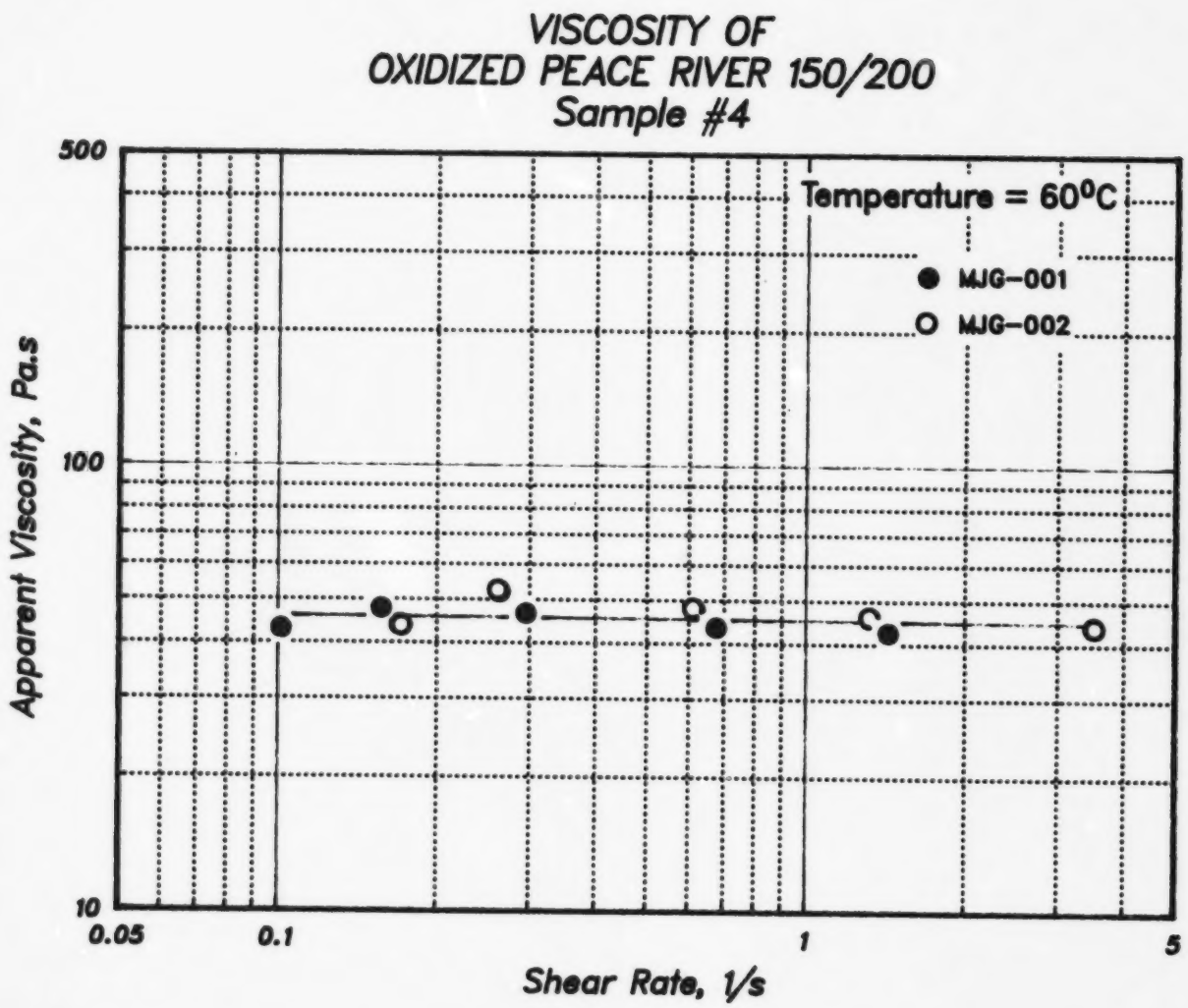

Shear Compliance of
90% Visbroken Cold Lake 10% Naphthene Aromatics
Sample 9B
Temperature = −20°C
MJG−1
MJG−2
MJG−3
−5
−5.5
−6
−6.5
−7
−7.5
−8
−1
0
1
2
3
4
log10 J(t) (m²/N)
log10 t (s)

APPENDIX 9

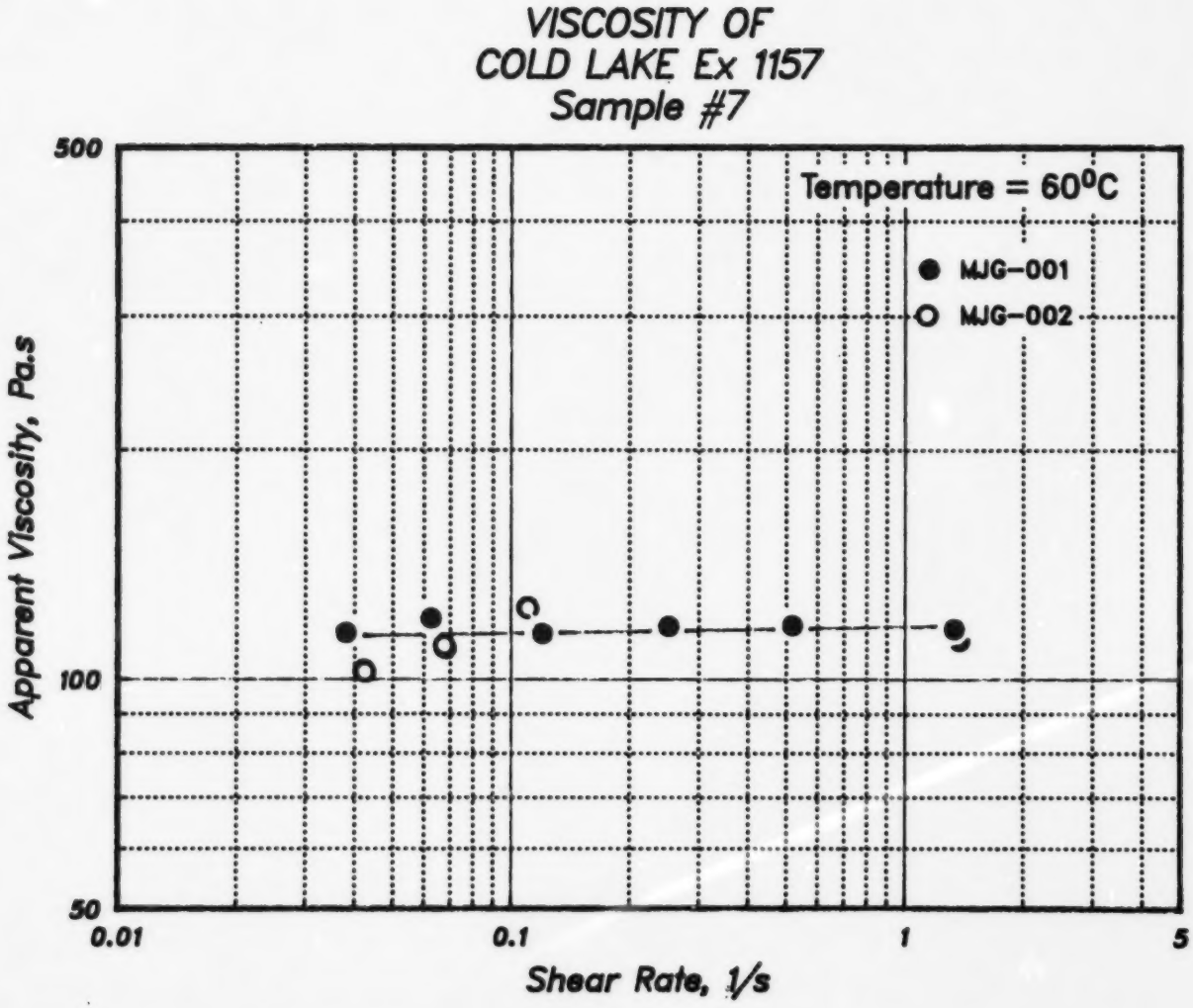

VISCOSITY OF
PEACE RIVER 150/200
Sample #6
Temperature = 60°C
MJG-001
MJG-002
Apparent Viscosity, Pa.s
500
100
10
0.05
0.1
1
5
Shear Rate, 1/s


VISCOSITY OF
88% PEACE RIVER 12% NAPHTHENE AROMATICS
Sample #10B
Temperature = 60°C
MJG-001
MJG-002
Apparent Viscosity, Pa.s
500
100
10
0.05
0.1
1
5
Shear Rate, 1/s

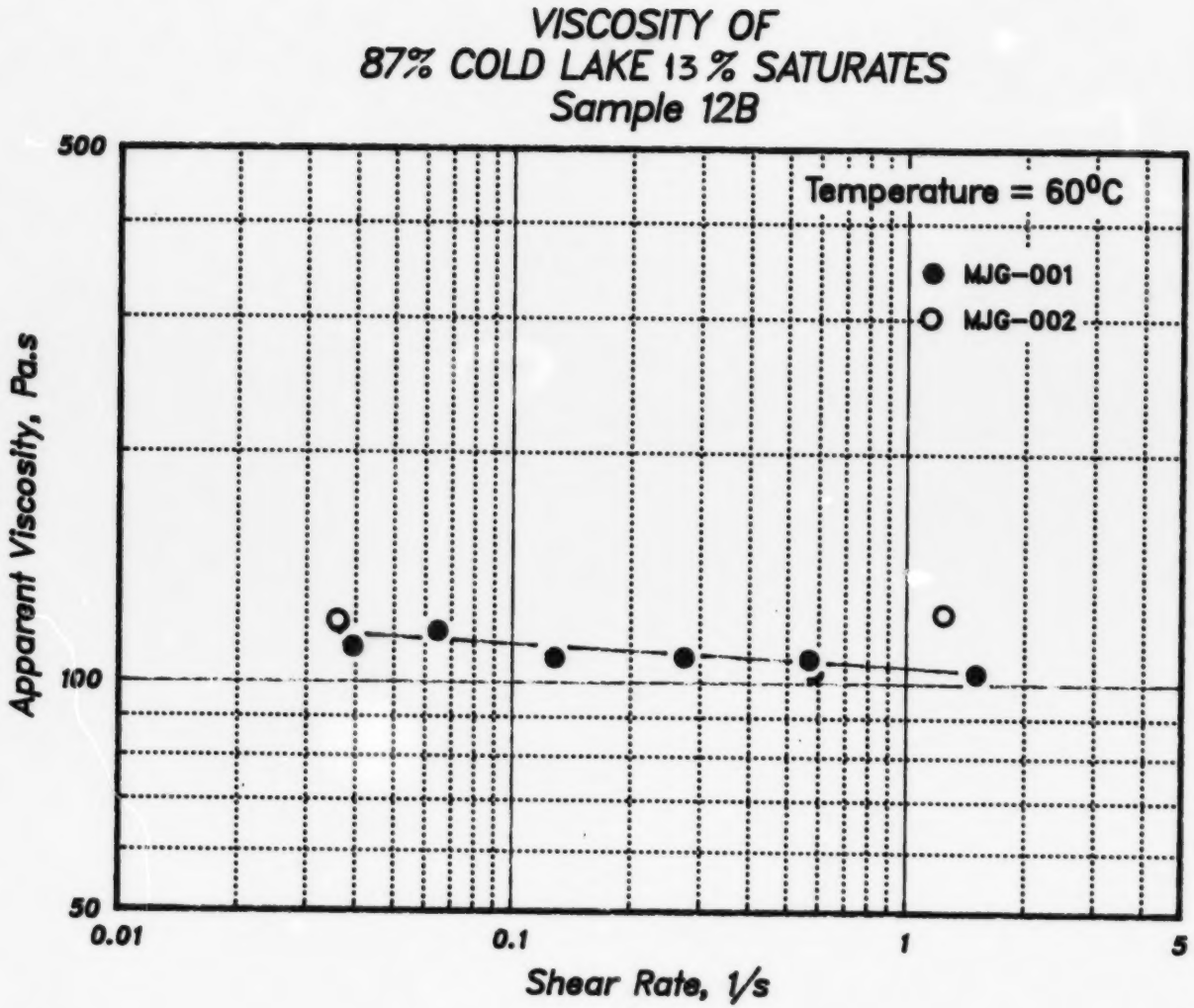

VISCOSITY OF
90% PEACE RIVER 10% POLAR AROMATICS + ASPHALTENES
Sample 11B
Temperature = 60°C
MJG-001
MJG-002
Apparent Viscosity, Pa.s
500
100
10
0.05
0.1
1
5
Shear Rate, 1/s


VISCOSITY OF
OXIDIZED PEACE RIVER 150/200
Sample #4
Temperature = 60°C
MJG-001
MJG-002
Apparent Viscosity, Pa.s
500
100
10
0.05
0.1
1
5
Shear Rate, 1/s

APPENDIX 13

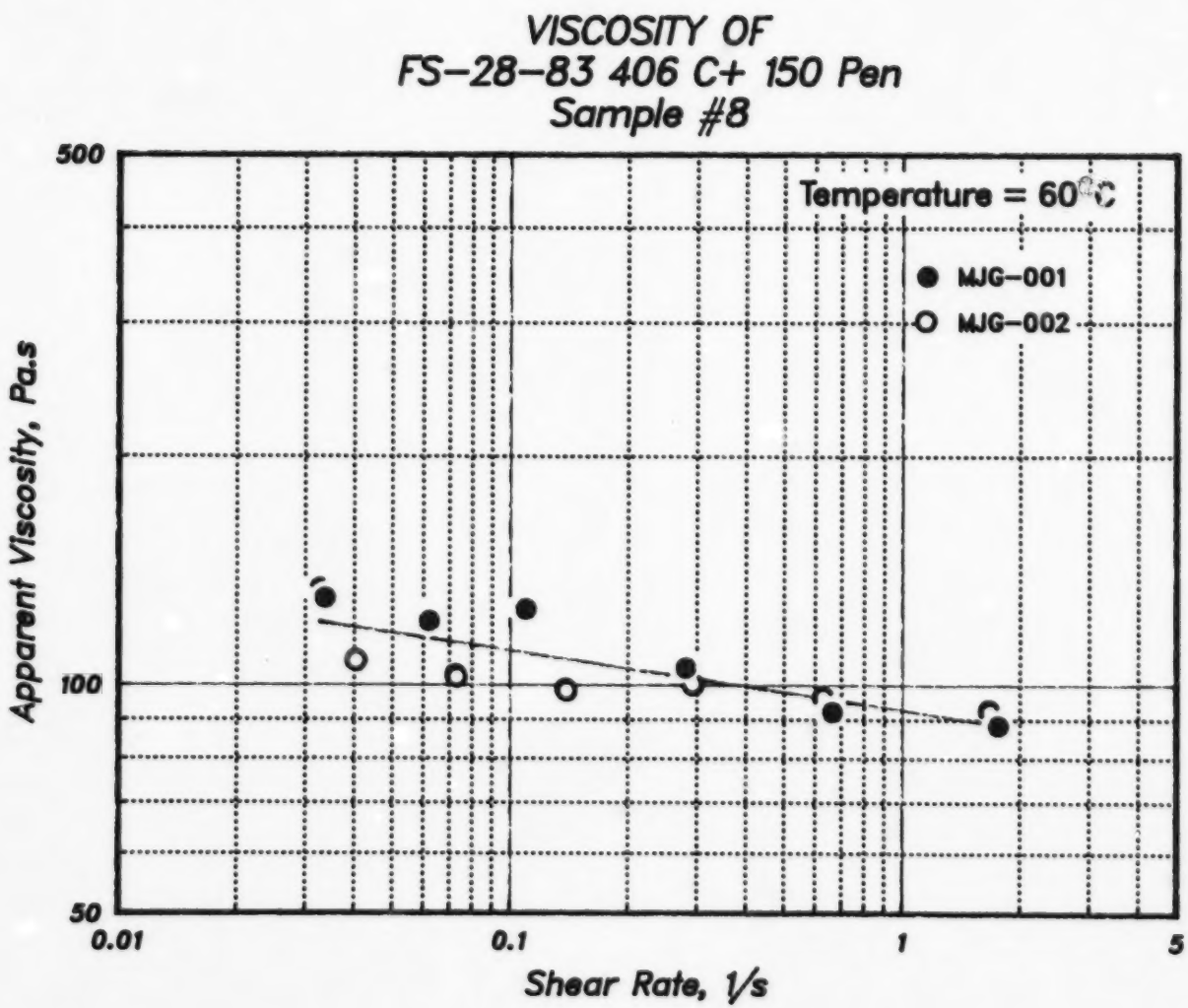

VISCOSITY OF
COLD LAKE Ex 1157
Sample #7
Temperature = 60°C
MJG-001
MJG-002
Apparent Viscosity, Pa.s
500
100
50
0.01
0.1
1
5
Shear Rate, 1/s

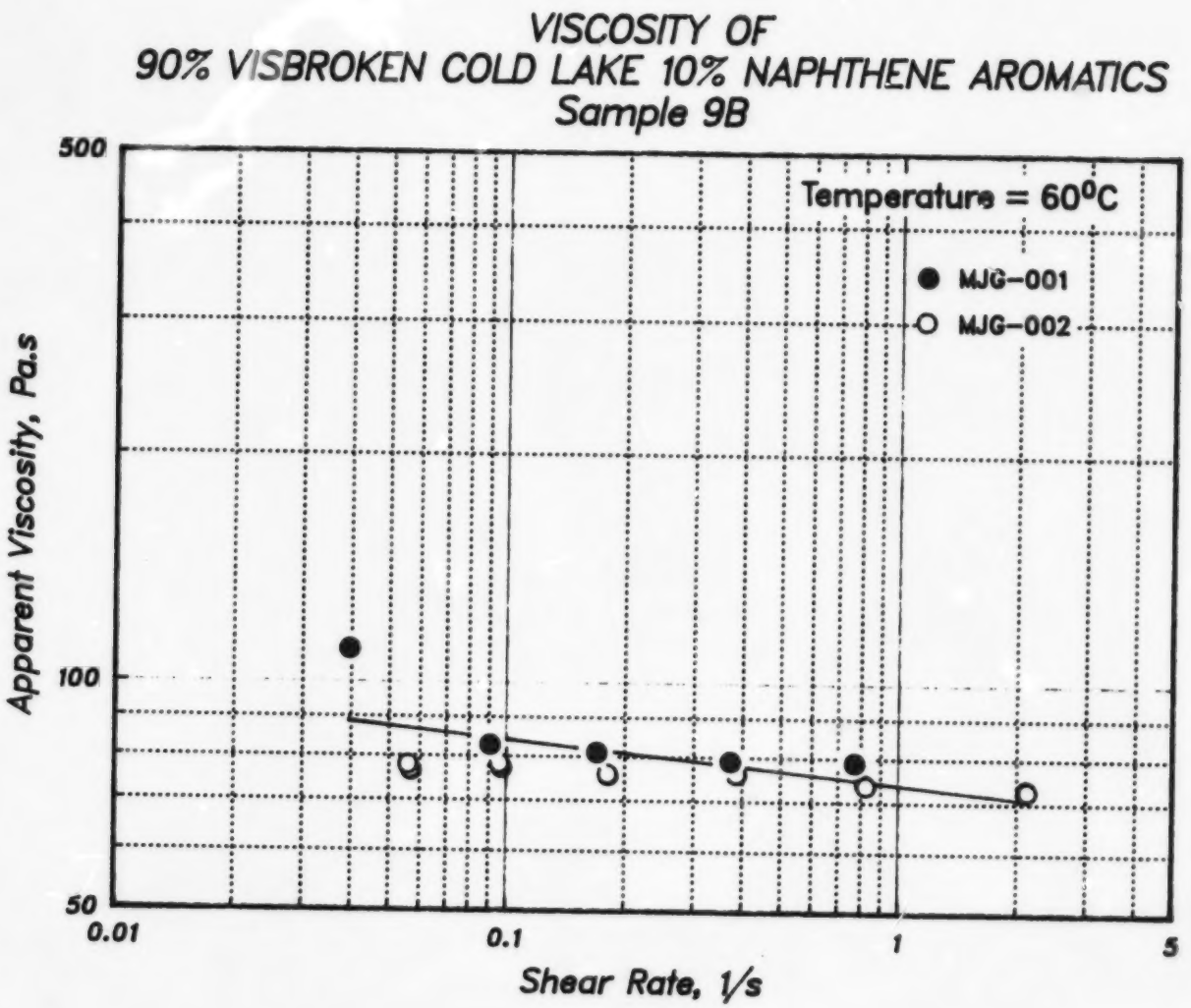
APPENDIX 14


VISCOSITY OF
87% COLD LAKE 13% SATURATES
Sample 12B
Temperature = 60°C
MJG-001
MJG-002
Apparent Viscosity, Pa.s
500
100
50
0.01
0.1
1
5
Shear Rate, 1/s

APPENDIX 15

FIGURE 20




VISCOSITY OF
90% VISBROKEN COLD LAKE 10% NAPHTHENE AROMATICS
Sample 9B
Temperature = 60°C
MJG-001
MJG-002
Apparent Viscosity, Pa.s
500
100
50
0.01
0.1
1
5
Shear Rate, 1/s

APPENDIX 17

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

PEACE RIVER 150/200

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	189
Viscosity at 60 C, Poises	252
Penetration Index	-1.92
Density at 15 C, kg/L	1.004

TEST CONDITIONS: TEST NO. MJG-2

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.239E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	4.257E-03	1.901E-08	0.000	-7.721
2	4.774E-03	2.133E-08	0.301	-7.671
5	5.702E-03	2.547E-08	0.699	-7.594
10	6.512E-03	2.909E-08	1.000	-7.536
20	7.703E-03	3.441E-08	1.301	-7.463
50	1.025E-02	4.578E-08	1.699	-7.339
100	1.257E-02	5.615E-08	2.000	-7.251
200	1.561E-02	6.971E-08	2.301	-7.157
500	1.787E-02	7.982E-08	2.699	-7.098
1000	2.446E-02	1.093E-07	3.000	-6.962

SPLE6

APPENDIX 18

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

PEACE RIVER 150/200

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	189
Viscosity at 60 C, Poises	252
Penetration Index	-1.92
Density at 15 C, kg/L	1.004

TEST CONDITIONS: TEST NO. MJG-3

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.238E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	5.936E-03	2.652E-08	0.000	-7.576
2	6.434E-03	2.875E-08	0.301	-7.541
5	7.332E-03	3.276E-08	0.699	-7.485
10	8.309E-03	3.713E-08	1.000	-7.430
20	9.769E-03	4.365E-08	1.301	-7.360
50	1.193E-02	5.332E-08	1.699	-7.273
100	1.509E-02	6.741E-08	2.000	-7.171
200	1.902E-02	8.497E-08	2.301	-7.071
500	2.748E-02	1.228E-07	2.699	-6.911
1000	3.584E-02	1.602E-07	3.000	-6.795

SPLE6

APPENDIX 19

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

88% PEACE RIVER 12% NAPHTHENE AROMATICS

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	184
Viscosity at 60 C, Poises	319
Penetration Index	-1.94
Density at 15 C, kg/L	1.009

TEST CONDITIONS: TEST NO. MJG-1

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.239E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	4.481E-03	2.002E-08	0.000	-7.699
2	4.950E-03	2.211E-08	0.301	-7.655
5	5.643E-03	2.521E-08	0.699	-7.598
10	6.317E-03	2.822E-08	1.000	-7.550
20	7.362E-03	3.288E-08	1.301	-7.483
50	9.168E-03	4.095E-08	1.699	-7.388
100	1.131E-02	5.051E-08	2.000	-7.297
200	1.411E-02	6.300E-08	2.301	-7.201
500	2.088E-02	9.327E-08	2.699	-7.030
1000	2.904E-02	1.297E-07	3.000	-6.887

SPLE10B

APPENDIX 20

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

88% PEACE RIVER 12% NAPHTHENE AROMATICS

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	184
Viscosity at 60 C, Poises	319
Penetration Index	-1.94
Density at 15 C, kg/L	1.009

TEST CONDITIONS: TEST NO. MJG-2

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.245E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	7.948E-03	3.540E-08	0.000	-7.451
2	8.494E-03	3.783E-08	0.301	-7.422
5	9.344E-03	4.162E-08	0.699	-7.381
10	1.045E-02	4.655E-08	1.000	-7.332
20	1.172E-02	5.221E-08	1.301	-7.282
50	1.383E-02	6.158E-08	1.699	-7.211
100	1.641E-02	7.307E-08	2.000	-7.136
200	2.199E-02	9.796E-08	2.301	-7.009
500	2.916E-02	1.299E-07	2.699	-6.886
1000	3.792E-02	1.689E-07	3.000	-6.772

SPLE10B

APPENDIX 21

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

90% PEACE RIVER 10% NAPHTHENE AROMATICS + ASPHALTENES

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	165
Viscosity at 60 C, Poises	846
Penetration Index	-1.50
Density at 15 C, kg/L	1.006

TEST CONDITIONS: TEST NO. MJG-1

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.239E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	4.481E-03	2.002E-08	0.000	-7.699
2	4.950E-03	2.211E-08	0.301	-7.655
5	5.643E-03	2.521E-08	0.699	-7.598
10	6.317E-03	2.822E-08	1.000	-7.550
20	7.362E-03	3.288E-08	1.301	-7.483
50	9.168E-03	4.095E-08	1.699	-7.388
100	1.131E-02	5.051E-08	2.000	-7.297
200	1.411E-02	6.300E-08	2.301	-7.201
500	2.088E-02	9.327E-08	2.699	-7.030
1000	2.904E-02	1.297E-07	3.000	-6.887

SPLE11B

APPENDIX 22

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

90% PEACE RIVER 10% NAPHTHENE AROMATICS + ASPHALTENES

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	165
Viscosity at 60 C, Poises	846
Penetration Index	-1.50
Density at 15 C, kg/L	1.006

TEST CONDITIONS: TEST NO. MJG-2

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.239E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	2.783E-03	1.242E-08	0.000	-7.906
2	3.349E-03	1.495E-08	0.301	-7.825
5	4.335E-03	1.936E-08	0.699	-7.713
10	5.399E-03	2.411E-08	1.000	-7.618
20	6.835E-03	3.052E-08	1.301	-7.515
50	9.527E-03	4.254E-08	1.699	-7.371
100	1.272E-02	5.681E-08	2.000	-7.246
200	1.709E-02	7.630E-08	2.301	-7.117
500	2.909E-02	1.299E-07	2.699	-6.886
1000	3.526E-02	1.575E-07	3.000	-6.803

SPLE11B

APPENDIX 23

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

90% PEACE RIVER 10% NAPHTHENE AROMATICS + ASPHALTENES

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	165
Viscosity at 60 C, Poises	846
Penetration Index	-1.50
Density at 15 C, kg/L	1.006

TEST CONDITIONS: TEST NO. MJG-3

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	1.915E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	2.451E-03	1.280E-08	0.000	-7.893
2	2.831E-03	1.479E-08	0.301	-7.830
5	3.525E-03	1.841E-08	0.699	-7.735
10	4.130E-03	2.157E-08	1.000	-7.666
20	4.804E-03	2.509E-08	1.301	-7.601
50	6.385E-03	3.335E-08	1.699	-7.477
100	7.616E-03	3.978E-08	2.000	-7.400
200	9.433E-03	4.927E-08	2.301	-7.307
500	1.324E-02	6.917E-08	2.699	-7.160
1000	1.763E-02	9.208E-08	3.000	-7.036

SPLE11B

APPENDIX 24

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

OXIDIZED PEACE RIVER 150/200

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	162
Viscosity at 60 C, Poises	272
Penetration Index	-0.13
Density at 15 C, kg/L	0.997

TEST CONDITIONS: TEST NO. MJG-2

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	3.535E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	3.661E-03	1.036E-08	0.000	-7.985
2	5.370E-03	1.519E-08	0.301	-7.819
5	8.260E-03	2.336E-08	0.699	-7.632
10	1.115E-02	3.154E-08	1.000	-7.501
20	1.480E-02	4.187E-08	1.301	-7.378
50	2.168E-02	6.132E-08	1.699	-7.212
100	2.865E-02	8.103E-08	2.000	-7.091
200	3.760E-02	1.064E-07	2.301	-6.973
500	5.492E-02	1.554E-07	2.699	-6.809
1000	7.443E-02	2.106E-07	3.000	-6.677

SPLE4

APPENDIX 25

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

OXIDIZED PEACE RIVER 150/200

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	162
Viscosity at 60 C, Poises	272
Penetration Index	-0.13
Density at 15 C, kg/L	0.997

TEST CONDITIONS: TEST NO. MJG-3

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.237E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	2.412E-03	1.078E-08	0.000	-7.967
2	3.290E-03	1.471E-08	0.301	-7.832
5	4.618E-03	2.064E-08	0.699	-7.685
10	6.014E-03	2.688E-08	1.000	-7.571
20	7.879E-03	3.522E-08	1.301	-7.453
50	1.122E-02	5.014E-08	1.699	-7.300
100	1.441E-02	6.442E-08	2.000	-7.191
200	1.870E-02	8.358E-08	2.301	-7.078
500	2.887E-02	1.291E-07	2.699	-6.889
1000	3.783E-02	1.691E-07	3.000	-6.772

SPLE4

APPENDIX 26

Date:08/09/02

CREEP COMPLIANCE IN SHEAR OF
COLD LAKE 150/200 EX 1157
(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	158
Viscosity at 60 C, Poises	845
Penetration Index	-0.98
Density at 15 C, kg/L	1.033

TEST CONDITIONS: TEST NO. MJG-8

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	3.537E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	6.083E-03	1.719E-08	0.000	-7.765
2	7.235E-03	2.045E-08	0.301	-7.689
5	9.432E-03	2.665E-08	0.699	-7.574
10	1.178E-02	3.329E-08	1.000	-7.478
20	1.499E-02	4.238E-08	1.301	-7.373
50	2.153E-02	6.086E-08	1.699	-7.216
100	2.950E-02	8.336E-08	2.000	-7.079
200	4.104E-02	1.160E-07	2.301	-6.936
500	6.672E-02	1.886E-07	2.699	-6.724
1000	9.698E-02	2.742E-07	3.000	-6.562

CL1157

APPENDIX 27

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF
COLD LAKE 150/200 EX 1157
(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	158
Viscosity at 60 C, Poises	845
Penetration Index	-0.98
Density at 15 C, kg/L	1.033

TEST CONDITIONS: TEST NO. MJG-12

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	3.547E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	5.643E-03	1.590E-08	0.000	-7.798
2	6.893E-03	1.943E-08	0.301	-7.712
5	9.322E-03	2.627E-08	0.699	-7.581
10	1.196E-02	3.371E-08	1.000	-7.472
20	1.577E-02	4.445E-08	1.301	-7.352
50	2.271E-02	6.401E-08	1.699	-7.194
100	3.346E-02	9.431E-08	2.000	-7.025
200	4.760E-02	1.342E-07	2.301	-6.872
500	7.965E-02	2.245E-07	2.699	-6.649
1000	1.213E-01	3.418E-07	3.000	-6.466

CL1157

APPENDIX 28

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

87% COLD LAKE 13% SATURATES

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	185
Viscosity at 60 C, Poises	686
Penetration Index	-0.54
Density at 15 C, kg/L	1.019

TEST CONDITIONS: TEST NO. MJG-1

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.236E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	1.048E-02	4.685E-08	0.000	-7.329
2	1.205E-02	5.386E-08	0.301	-7.269
5	1.475E-02	6.592E-08	0.699	-7.181
10	1.800E-02	8.047E-08	1.000	-7.094
20	2.131E-02	9.524E-08	1.301	-7.021
50	3.086E-02	1.380E-07	1.699	-6.860
100	4.221E-02	1.887E-07	2.000	-6.724
200	5.993E-02	2.679E-07	2.301	-6.572
500	9.656E-02	4.317E-07	2.699	-6.365
1000	1.417E-01	6.339E-07	3.000	-6.198

SPLE12B

APPENDIX 29

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

87% COLD LAKE 13% SATURATES

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	185
Viscosity at 60 C, Poises	686
Penetration Index	-0.54
Density at 15 C, kg/L	1.019

TEST CONDITIONS: TEST NO. MJG-2

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	1.910E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	7.459E-03	3.900E-08	0.000	-7.409
2	1.001E-02	5.232E-08	0.301	-7.281
5	1.517E-02	7.929E-08	0.699	-7.101
10	2.091E-02	1.093E-07	1.000	-6.961
20	2.947E-02	1.541E-07	1.301	-6.812
50	4.818E-02	2.519E-07	1.699	-6.599
100	7.127E-02	3.728E-07	2.000	-6.429
200	1.069E-01	5.592E-07	2.301	-6.252
500	1.832E-01	9.585E-07	2.699	-6.018
1000	2.815E-01	1.474E-06	3.000	-5.831

SPLE12B

APPENDIX 30

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

87% COLD LAKE 13% SATURATES

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	185
Viscosity at 60 C, Poises	686
Penetration Index	-0.54
Density at 15 C, kg/L	1.019

TEST CONDITIONS: TEST NO. MJG-3

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	1.911E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	6.629E-03	3.466E-08	0.000	-7.460
2	8.455E-03	4.420E-08	0.301	-7.355
5	1.193E-02	6.236E-08	0.699	-7.205
10	1.568E-02	8.197E-08	1.000	-7.086
20	2.069E-02	1.082E-07	1.301	-6.966
50	3.144E-02	1.644E-07	1.699	-6.784
100	4.438E-02	2.320E-07	2.000	-6.634
200	6.349E-02	3.320E-07	2.301	-6.479
500	1.037E-01	5.424E-07	2.699	-6.266
1000	1.489E-01	7.790E-07	3.000	-6.108

SPLE12B

APPENDIX 31

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

FS-28-83 406 C+

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	150
Viscosity at 60 C, Poises	716
Penetration Index	-0.61
Density at 15 C, kg/L	1.061

TEST CONDITIONS: TEST NO. MJG-1

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	3.537E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	3.857E-03	1.090E-08	0.000	-7.963
2	5.868E-03	1.658E-08	0.301	-7.780
5	9.568E-03	2.704E-08	0.699	-7.568
10	1.385E-02	3.914E-08	1.000	-7.407
20	1.962E-02	5.546E-08	1.301	-7.256
50	3.225E-02	9.114E-08	1.699	-7.040
100	4.439E-02	1.255E-07	2.000	-6.901
200	6.092E-02	1.722E-07	2.301	-6.764
500	9.356E-02	2.645E-07	2.699	-6.578
1000	1.316E-01	3.720E-07	3.000	-6.429

SPLE8

APPENDIX 32

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

FS-28-83 406 C+

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	150
Viscosity at 60 C, Poises	716
Penetration Index	-0.61
Density at 15 C, kg/L	1.061

TEST CONDITIONS: TEST NO. MJG-2

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	3.535E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	3.027E-03	8.559E-09	0.000	-8.068
2	4.696E-03	1.328E-08	0.301	-7.877
5	7.801E-03	2.206E-08	0.699	-7.656
10	1.153E-02	3.260E-08	1.000	-7.487
20	1.651E-02	4.669E-08	1.301	-7.331
50	2.664E-02	7.533E-08	1.699	-7.123
100	3.759E-02	1.063E-07	2.000	-6.973
200	5.331E-02	1.508E-07	2.301	-6.822
500	8.437E-02	2.386E-07	2.699	-6.622
1000	1.212E-01	3.428E-07	3.000	-6.465

SPLE8

APPENDIX 33

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

90%VISBROKEN COLD LAKE 10%NAPHTHENE AROM

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	178
Viscosity at 60 C, Poises	524
Penetration Index	-0.62
Density at 15 C, kg/L	1.055

TEST CONDITIONS: TEST NO. MJG-1

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.237E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	1.115E-02	4.981E-08	0.000	-7.303
2	1.252E-02	5.592E-08	0.301	-7.252
5	1.582E-02	7.063E-08	0.699	-7.151
10	2.099E-02	9.372E-08	1.000	-7.028
20	2.556E-02	1.142E-07	1.301	-6.942
50	3.691E-02	1.649E-07	1.699	-6.783
100	4.985E-02	2.227E-07	2.000	-6.652
200	6.976E-02	3.116E-07	2.301	-6.506
500	1.114E-01	4.976E-07	2.699	-6.303
1000	1.629E-01	7.282E-07	3.000	-6.138

SPLE9B

APPENDIX 34

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

90%VISBROKEN COLD LAKE 10%NAPHTHENE AROM

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	178
Viscosity at 60 C, Poises	524
Penetration Index	-0.62
Density at 15 C, kg/L	1.055

TEST CONDITIONS: TEST NO. MJG-2

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.237E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	5.575E-03	2.490E-08	0.000	-7.604
2	6.864E-03	3.066E-08	0.301	-7.513
5	9.499E-03	4.243E-08	0.699	-7.372
10	1.210E-02	5.405E-08	1.000	-7.267
20	1.585E-02	7.080E-08	1.301	-7.150
50	2.502E-02	1.118E-07	1.699	-6.952
100	3.298E-02	1.474E-07	2.000	-6.832
200	4.513E-02	2.016E-07	2.301	-6.695
500	7.101E-02	3.173E-07	2.699	-6.499
1000	1.027E-01	4.588E-07	3.000	-6.338

SPLE9B

APPENDIX 35

Date:88/09/02

CREEP COMPLIANCE IN SHEAR OF

90%VISBROKEN COLD LAKE 10%NAPHTHENE AROM

(SLIDING PLATE RHEOMETER)

BITUMEN PROPERTIES:

Penetration at 25 C	178
Viscosity at 60 C, Poises	524
Penetration Index	-0.62
Density at 15 C, kg/L	1.055

TEST CONDITIONS: TEST NO. MJG-3

Temperature, deg C	-20.0
Specimen Thickness, mm	10.0
Shear Stress, N/M2	2.237E+04

Loading Time Seconds	Displacement mm	Shear Compliance 1/Pa	log t	log J(t)
1	1.063E-02	4.749E-08	0.000	-7.323
2	1.158E-02	5.174E-08	0.301	-7.286
5	1.346E-02	6.017E-08	0.699	-7.221
10	1.549E-02	6.921E-08	1.000	-7.160
20	1.819E-02	8.127E-08	1.301	-7.090
50	2.326E-02	1.040E-07	1.699	-6.983
100	2.744E-02	1.226E-07	2.000	-6.911
200	3.560E-02	1.591E-07	2.301	-6.798
500	6.009E-02	2.686E-07	2.699	-6.571
1000	1.027E-01	4.591E-07	3.000	-6.338

SPLE9B

APPENDIX 36

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-024 Description : SAMPLE #6 PEACE RIVER 150/200

Penetration at 25 C (100/5) : 190
10 C (100/5) : 29.3
4 C (100/5) : 13.3
0 C (200/60) : 27.7
45 C (50/5) :

Viscosity at 60 C : 252.0 Poise
100 C : 781.0 cSt
135 C : 130 0 cSt
150 C :

Penetration Index : -1.92
Penetration Ratio : 25.4

Softening Point D36 : 41.4 C
Density at 15 C : kg/L

Test ID : MJG-001 TEST TEMPERATURE : 60.0 C DATE : 88 07 05

Calibration No : 4
Cone : 8

Shear Stress : 3.129 Pa/g
Shear Strain : 2.173 /deg
Friction : 0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	2	35.0	4.346E+00	4.346	1.242E-01	3.500E+01	1.000E+00
1.998	4	69.9	4.346E+00	8.692	1.243E-01	3.495E+01	2.000E+00
1.998	6	104.4	4.346E+00	13.038	1.249E-01	3.480E+01	3.000E+00
3.000	4	42.1	7.481E+00	8.692	2.065E-01	3.624E+01	1.162E+00
3.000	8	84.2	7.481E+00	17.384	2.065E-01	3.624E+01	2.324E+00
3.000	12	127.0	7.481E+00	26.076	2.053E-01	3.644E+01	3.485E+00
4.999	5	32.1	1.374E+01	10.865	3.385E-01	4.058E+01	7.910E-01
4.999	10	65.0	1.374E+01	21.730	3.343E-01	4.109E+01	1.582E+00
4.999	15	97.9	1.374E+01	32.595	3.329E-01	4.126E+01	2.373E+00
10.000	10	29.2	2.938E+01	21.730	7.442E-01	3.949E+01	7.395E-01
10.000	20	58.9	2.938E+01	43.460	7.379E-01	3.982E+01	1.479E+00
10.000	30	87.9	2.938E+01	65.190	7.416E-01	3.962E+01	2.219E+00
20.034	20	27.6	6.078E+01	43.460	1.575E+00	3.860E+01	7.150E-01
20.034	40	54.9	6.078E+01	86.920	1.583E+00	3.839E+01	1.430E+00
20.034	60	82.1	6.078E+01	130.380	1.588E+00	3.827E+01	2.145E+00
50.044	50	26.0	1.547E+02	108.650	4.179E+00	3.702E+01	7.024E-01
50.044	100	52.1	1.547E+02	217.300	4.171E+00	3.709E+01	1.405E+00
50.044	150	78.0	1.547E+02	325.950	4.179E+00	3.702E+01	2.107E+00

APPENDIX 37

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-024 Description : SAMPLE #6 PEACE RIVER 150/200

Penetration at 25 C (100/5) :	190	Viscosity at 60 C :	252.0 Poise
10 C (100/5) :	29.3	100 C :	781.0 cSt
4 C (100/5) :	13.3	135 C :	130.0 cSt
0 C (200/60) :	27.7	150 C :	
45 C (50/5) :			
Penetration Index :	-1.92	Softening Point D36 :	41.4 C
Penetration Ratio :	25.4	Density at 15 C :	kg/L

Test ID : MJG-002 TEST TEMPERATURE : 60.0 C DATE : 88 07 06

Calibration No :	4
Cone :	8
Shear Stress :	3.129 Pa/g
Shear Strain :	2.173 /deg
Friction :	0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	2	43.8	4.346E+00	4.346	9.922E-02	4.380E+01	1.000E+00
1.998	4	86.8	4.346E+00	8.692	1.001E-01	4.340E+01	2.000E+00
1.998	6	130.2	4.346E+00	13.038	1.001E-01	4.340E+01	3.000E+00
3.000	4	49.3	7.481E+00	8.692	1.763E-01	4.243E+01	1.162E+00
3.000	8	98.3	7.481E+00	17.384	1.768E-01	4.230E+01	2.324E+00
3.000	12	147.2	7.481E+00	26.076	1.771E-01	4.223E+01	3.485E+00
4.999	5	32.1	1.374E+01	10.865	3.385E-01	4.058E+01	7.910E-01
4.999	10	64.2	1.374E+01	21.730	3.385E-01	4.058E+01	1.582E+00
4.999	15	67.6	1.374E+01	32.595	4.822E-01	2.849E+01	2.373E+00
10.000	10	30.2	2.938E+01	21.730	7.195E-01	4.084E+01	7.395E-01
10.000	20	59.9	2.938E+01	43.460	7.255E-01	4.050E+01	1.479E+00
10.000	30	89.7	2.938E+01	65.190	7.268E-01	4.043E+01	2.219E+00
20.034	20	28.7	6.078E+01	43.460	1.514E+00	4.014E+01	7.150E-01
20.034	40	57.1	6.078E+01	86.920	1.522E+00	3.993E+01	1.430E+00
20.034	60	85.7	6.078E+01	130.380	1.521E+00	3.995E+01	2.145E+00
50.044	50	27.1	1.547E+02	108.650	4.009E+00	3.858E+01	7.024E-01
50.044	100	54.1	1.547E+02	217.300	4.017E+00	3.851E+01	1.405E+00
50.044	150	81.3	1.547E+02	325.950	4.009E+00	3.858E+01	2.107E+00

APPENDIX 38

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-028 Description : SPLE #108 88% PEACE RIVER 12% NAPH AROM

Penetration at 25 C (100/5) : 184
10 C (100/5) : 27.8
4 C (100/5) : 13.5
0 C (200/60) : 28.8
45 C (50/5) :

Viscosity at 60 C : 319.0 Poise
100 C : 935.0 cSt
135 C : 151.0 cSt
150 C :

Penetration Index : -1.94
Penetration Ratio : 25.0

Softening Point D36 : 41.1 C
Density at 15 C : kg/L

Test ID : MJG-001 TEST TEMPERATURE : 60.0 C DATE : 88 07 12

Calibration No : 4
Cone : 8

Shear Stress : 3.129 Pa/g
Shear Strain : 2.173 /deg
Friction : 0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	2	43.9	4.346E+00	4.346	9.900E-02	4.390E+01	1.000E+00
1.998	4	87.6	4.346E+00	8.692	9.922E-02	4.380E+01	2.000E+00
1.998	6	131.9	4.346E+00	13.038	9.885E-02	4.397E+01	3.000E+00
3.000	2	26.0	7.481E+00	4.346	1.672E-01	4.476E+01	5.809E-01
3.000	4	52.5	7.481E+00	8.692	1.656E-01	4.519E+01	1.162E+00
3.000	6	79.0	7.481E+00	13.038	1.650E-01	4.533E+01	1.743E+00
4.999	3	21.6	1.374E+01	6.519	3.018E-01	4.551E+01	4.746E-01
4.999	6	43.3	1.374E+01	13.038	3.011E-01	4.562E+01	9.492E-01
4.999	9	65.0	1.374E+01	19.557	3.009E-01	4.565E+01	1.424E+00
10.000	10	30.9	2.938E+01	21.730	7.032E-01	4.178E+01	7.395E-01
10.000	20	62.2	2.938E+01	43.460	6.987E-01	4.206E+01	1.479E+00
10.000	30	93.4	2.938E+01	65.190	6.980E-01	4.210E+01	2.219E+00
20.034	20	28.5	6.078E+01	43.460	1.525E+00	3.986E+01	7.150E-01
20.034	40	56.6	6.078E+01	86.920	1.536E+00	3.958E+01	1.430E+00
20.034	60	84.7	6.078E+01	130.380	1.539E+00	3.949E+01	2.145E+00
50.044	50	26.6	1.547E+02	108.650	4.085E+00	3.787E+01	7.024E-01
50.044	100	53.2	1.547E+02	217.300	4.085E+00	3.787E+01	1.405E+00
50.044	150	79.7	1.547E+02	325.950	4.090E+00	3.782E+01	2.107E+00

APPENDIX 39

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-028 Description : SPLE #108 88% PEACE RIVER 12% NAPH AROM

Penetration at 25 C (100/5) :	184	Viscosity at 60 C :	319.0 Poise
10 C (100/5) :	27.8	100 C :	935.0 cSt
4 C (100/5) :	13.5	135 C :	151.0 cSt
0 C (200/60) :	28.8	150 C :	
45 C (50/5) :			
Penetration Index :	-1.94	Softening Point D36 :	41.1 C
Penetration Ratio :	25.0	Density at 15 C :	kg/L

Test ID : MJG-002 TEST TEMPERATURE : 60.0 C DATE : 88 07 13

Calibration No : 4
Cone : 8

Shear Stress : 3.129 Pa/g
Shear Strain : 2.173 /deg
Friction : 0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	2	71.7	4.346E+00	4.346	6.061E-02	7.170E+01	1.000E+00
1.998	4	141.9	4.346E+00	8.692	6.125E-02	7.095E+01	2.000E+00
1.998	6	208.5	4.346E+00	13.038	6.253E-02	6.950E+01	3.000E+00
3.000	2	31.1	7.481E+00	4.346	1.397E-01	5.354E+01	5.809E-01
3.000	4	62.0	7.481E+00	8.692	1.402E-01	5.337E+01	1.162E+00
3.000	6	93.1	7.481E+00	13.038	1.400E-01	5.342E+01	1.743E+00
4.999	5	38.7	1.374E+01	10.865	2.807E-01	4.893E+01	7.910E-01
4.999	10	77.5	1.374E+01	21.730	2.804E-01	4.899E+01	1.582E+00
4.999	15	115.9	1.374E+01	32.595	2.812E-01	4.884E+01	2.373E+00
10.000	10	34.5	2.938E+01	21.730	6.299E-01	4.665E+01	7.395E-01
10.000	20	68.7	2.938E+01	43.460	6.326E-01	4.645E+01	1.479E+00
10.000	30	103.1	2.938E+01	65.190	6.323E-01	4.647E+01	2.219E+00
20.034	20	32.6	6.078E+01	43.460	1.333E+00	4.559E+01	7.150E-01
20.034	40	65.2	6.078E+01	86.920	1.333E+00	4.559E+01	1.430E+00
20.034	60	98.0	6.078E+01	130.380	1.330E+00	4.569E+01	2.145E+00
50.044	50	31.0	1.547E+02	108.650	3.505E+00	4.413E+01	7.024E-01
50.044	100	61.9	1.547E+02	217.300	3.511E+00	4.406E+01	1.405E+00
50.044	150	92.6	1.547E+02	325.950	3.520E+00	4.394E+01	2.107E+00

APPENDIX 40

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-029 Description : SPLE #11B 90% PEACE RIVER 10% P ARM,ASPH

Penetration at 25 C (100/5) :	165	Viscosity at 60 C :	286.0 Poise
10 C (100/5) :	28.3	100 C :	846.0 cSt
4 C (100/5) :	14.8	135 C :	140.0 cSt
0 C (200/60) :	29	150 C :	
45 C (50/5) :			
Penetration Index :	-1.50	Softening Point D36 :	43.8 C
Penetration Ratio :	27.8	Density at 15 C :	kg/L

Test ID : MJG-001 TEST TEMPERATURE : 60.0 C DATE : 88 07 12

Calibration No : 4
Cone : B

Shear Stress : 3.129 Pa/g
Shear Strain : 2.173 /deg
Friction : 0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	2	44.7	4.346E+00	4.346	9.723E-02	4.470E+01	1.000E+00
1.998	4	93.0	4.346E+00	8.692	9.346E-02	4.650E+01	2.000E+00
1.998	6	141.1	4.346E+00	13.038	9.240E-02	4.704E+01	3.000E+00
3.000	3	41.7	7.481E+00	6.519	1.563E-01	4.786E+01	8.714E-01
3.000	6	83.6	7.481E+00	13.038	1.560E-01	4.797E+01	1.743E+00
3.000	9	125.9	7.481E+00	19.557	1.553E-01	4.816E+01	2.614E+00
4.999	5	37.2	1.374E+01	10.865	2.921E-01	4.703E+01	7.910E-01
4.999	10	74.8	1.374E+01	21.730	2.905E-01	4.728E+01	1.582E+00
4.999	15	112.0	1.374E+01	32.595	2.910E-01	4.720E+01	2.373E+00
10.000	10	33.1	2.938E+01	21.730	6.565E-01	4.476E+01	7.395E-01
10.000	20	66.9	2.938E+01	43.460	6.496E-01	4.523E+01	1.479E+00
10.000	30	100.3	2.938E+01	65.190	6.500E-01	4.521E+01	2.219E+00
20.034	20	31.1	6.078E+01	43.460	1.397E+00	4.349E+01	7.150E-01
20.034	40	62.0	6.078E+01	86.920	1.402E+00	4.335E+01	1.430E+00
20.034	60	92.8	6.078E+01	130.380	1.405E+00	4.326E+01	2.145E+00
50.044	50	28.7	1.547E+02	108.650	3.786E+00	4.086E+01	7.024E-01
50.044	100	57.1	1.547E+02	217.300	3.806E+00	4.065E+01	1.405E+00
50.044	150	85.5	1.547E+02	325.950	3.812E+00	4.057E+01	2.107E+00

APPENDIX 41

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-029 Description : SPLE #11B 90% PEACE RIVER 10% P ARM,ASPH

Penetration at 25 C (100/5) :	165	Viscosity at 60 C :	286.0 Poise
10 C (100/5) :	28.3	100 C :	846.0 cSt
4 C (100/5) :	14.8	135 C :	140.0 cSt
0 C (200/60) :	29	150 C :	
45 C (50/5) :			
Penetration Index :	-1.50	Softening Point D36 :	43.8 C
Penetration Ratio :	27.8	Density at 15 C :	kg/L

Test ID : MJG-002 TEST TEMPERATURE : 60.0 C DATE : 88 07 14

Calibration No :	4	Shear Stress :	3.129 Pa/g
Cone :	8	Shear Strain :	2.173 /deg
		Friction :	0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	2	47.8	4.346E+00	4.346	9.092E-02	4.780E+01	1.000E+00
1.998	4	94.8	4.346E+00	8.692	9.169E-02	4.740E+01	2.000E+00
1.998	6	140.7	4.346E+00	13.038	9.267E-02	4.690E+01	3.000E+00
3.000	3	42.0	7.481E+00	6.519	1.552E-01	4.820E+01	8.714E-01
3.000	6	84.2	7.481E+00	13.038	1.548E-01	4.832E+01	1.743E+00
3.000	9	126.4	7.481E+00	19.557	1.547E-01	4.835E+01	2.614E+00
4.999	5	36.5	1.374E+01	10.865	2.977E-01	4.615E+01	7.910E-01
4.999	10	72.8	1.374E+01	21.730	2.985E-01	4.602E+01	1.582E+00
4.999	15	109.2	1.374E+01	32.595	2.985E-01	4.602E+01	2.373E+00
10.000	10	33.0	2.938E+01	21.730	6.585E-01	4.462E+01	7.395E-01
10.000	20	66.1	2.938E+01	43.460	6.575E-01	4.469E+01	1.479E+00
10.000	30	99.1	2.938E+01	65.190	6.578E-01	4.467E+01	2.219E+00
20.034	20	31.3	6.078E+01	43.460	1.388E+00	4.377E+01	7.150E-01
20.034	40	62.7	6.078E+01	86.920	1.386E+00	4.384E+01	1.430E+00
20.034	60	94.3	6.078E+01	130.380	1.383E+00	4.396E+01	2.145E+00
50.044	50	29.2	1.547E+02	108.650	3.721E+00	4.157E+01	7.024E-01
50.044	100	58.6	1.547E+02	217.300	3.708E+00	4.171E+01	1.405E+00
50.044	150	87.9	1.547E+02	325.950	3.708E+00	4.171E+01	2.107E+00

APPENDIX 42

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-023 Description : SAMPLE #4 OXIDIZED PEACE RIVER 150/200

Penetration at 25 C (100/5) :	162	Viscosity at 60 C :	272.0 Poise
10 C (100/5) :	39.7	100 C :	752.0 cSt
4 C (100/5) :	22.2	135 C :	127.0 cSt
0 C (200/60) :	43.5	150 C :	
45 C (50/5) :			
Penetration Index :	-0.13	Softening Point D36 :	42.9 C
Penetration Ratio :	40.0	Density at 15 C :	kg/L

Test ID : MJG-001 TEST TEMPERATURE : 60.0 C DATE : 88 07 08

Calibration No :	4	Shear Stress :	3.129 Pa/g
Cone :	8	Shear Strain :	2.173 /deg
		Friction :	0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	2	43.1	4.346E+00	4.346	1.008E-01	4.310E+01	1.000E+00
1.998	4	86.3	4.346E+00	8.692	1.007E-01	4.315E+01	2.000E+00
1.998	6	129.4	4.346E+00	13.038	1.008E-01	4.314E+01	3.000E+00
3.000	3	41.8	7.481E+00	6.519	1.560E-01	4.797E+01	8.714E-01
3.000	6	83.8	7.481E+00	13.038	1.556E-01	4.809E+01	1.743E+00
3.000	9	125.8	7.481E+00	19.557	1.555E-01	4.812E+01	2.614E+00
4.999	5	37.0	1.374E+01	10.8[illegible]	2.936E-01	4.678E+01	7.910E-01
4.999	10	74.3	1.374E+01	21.77[illegible]	2.925E-01	4.697E+01	1.582E+00
4.999	15	111.6	1.374E+01	32.595	2.921E-01	4.703E+01	2.373E+00
10.000	10	32.3	2.938E+01	21.730	6.728E-01	4.368E+01	7.395E-01
10.000	20	65.0	2.938E+01	43.460	6.686E-01	4.395E+01	1.479E+00
10.000	30	97.5	2.938E+01	65.190	6.686E-01	4.395E+01	2.219E+00
20.034	20	30.5	6.078E+01	43.460	1.425E+00	4.266E+01	7.150E-01
20.034	40	60.9	6.078E+01	86.920	1.427E+00	4.259E+01	1.430E+00
20.034	60	91.3	6.078E+01	130.380	1.428E+00	4.256E+01	2.145E+00

APPENDIX 43

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-023 Description : SAMPLE #4 OXIDIZED PEACE RIVER 150/200

Penetration at 25 C (100/5) :	162	Viscosity at 60 C :	272.0 Poise
10 C (100/5) :	39.7	100 C :	752.0 cSt
4 C (100/5) :	22.2	135 C :	127.0 cSt
0 C (200/60) :	43.5	150 C :	
45 C (50/5) :			
Penetration Index :	-0.13	Softening Point D36 :	42.9 C
Penetration Ratio :	40.0	Density at 15 C :	kg/L

Test ID : MJG-002 TEST TEMPERATURE : 60.0 C DATE : 88 07 11

Calibration No :	4	Shear Stress :	3.129 Pa/g
Cone :	8	Shear Strain :	2.173 /deg
		Friction :	0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	2	44.1	4.346E+00	4.346	9.855E-02	4.410E+01	1.000E+00
1.998	4	87.8	4.346E+00	8.692	9.900E-02	4.390E+01	2.000E+00
1.998	6	131.5	4.346E+00	13.038	9.915E-02	4.384E+01	3.000E+00
3.000	3	38.1	7.481E+00	6.519	1.711E-01	4.372E+01	8.714E-01
3.000	6	76.4	7.481E+00	13.038	1.707E-01	4.384E+01	1.743E+00
3.000	9	114.9	7.481E+00	19.557	1.702E-01	4.395E+01	2.614E+00
4.999	5	41.6	1.374E+01	10.865	2.612E-01	5.259E+01	7.910E-01
4.999	10	82.6	1.374E+01	21.730	2.631E-01	5.221E+01	1.582E+00
4.999	15	124.0	1.374E+01	32.595	2.629E-01	5.226E+01	2.373E+00
10.000	10	35.5	2.938E+01	21.730	6.121E-01	4.800E+01	7.395E-01
10.000	20	70.7	2.938E+01	43.460	6.147E-01	4.780E+01	1.479E+00
10.000	30	105.7	2.938E+01	65.190	6.167E-01	4.764E+01	2.219E+00
20.034	20	32.9	6.078E+01	43.460	1.321E+00	4.601E+01	7.150E-01
20.034	40	65.6	6.078E+01	86.920	1.325E+00	4.587E+01	1.430E+00
20.034	60	98.6	6.078E+01	130.380	1.322E+00	4.597E+01	2.145E+00
50.044	50	30.8	1.547E+02	108.650	3.528E+00	4.385E+01	7.024E-01
50.044	100	61.8	1.547E+02	217.300	3.516E+00	4.399E+01	1.405E+00
50.044	150	92.6	1.547E+02	325.950	3.520E+00	4.394E+01	2.107E+00

APPENDIX 44

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-025 Description : SAMPLE #7 COLD LAKE 150/200 EX 1157

Penetration at 25 C (100/5) : 158
10 C (100/5) : 32.5
4 C (100/5) : 15.5
0 C (200/60) : 37.2
45 C (50/5) :

Viscosity at 60 C : 845.0 Poise
100 C : 1897.0 cSt
135 C : 255.0 cSt
150 C :

Penetration Index : -0.98
Penetration Ratio : 37.5

Softening Point D36 : 40.0 C
Density at 15 C : kg/L

Test ID : MJG-001 TEST TEMPERATURE : 60.0 C DATE : 88 07 06

Calibration No : 4
Cone : 8

Shear Stress : 3.129 Pa/g
Shear Strain : 2.173 /deg
Friction : 0.609 g

Load (g)	Rotation (deg)	Cumulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	1	57.6	4.346E+00	2.173	3.773E-02	1.152E+02	5.000E-01
1.998	2	114.9	4.346E+00	4.346	3.782E-02	1.149E+02	1.000E+00
1.998	3	172.7	4.346E+00	6.519	3.775E-02	1.151E+02	1.500E+00
3.000	1	35.0	7.481E+00	2.173	6.209E-02	1.205E+02	2.905E-01
3.000	2	69.7	7.481E+00	4.346	6.235E-02	1.200E+02	5.809E-01
3.000	3	104.7	7.481E+00	6.519	6.226E-02	1.202E+02	8.714E-01
4.999	2	36.4	1.374E+01	4.346	1.194E-01	1.150E+02	3.164E-01
4.999	4	73.2	1.374E+01	8.692	1.187E-01	1.157E+02	6.328E-01
4.999	6	109.9	1.374E+01	13.038	1.186E-01	1.158E+02	9.492E-01
10.000	4	34.8	2.938E+01	8.692	2.498E-01	1.176E+02	2.958E-01
10.000	8	69.8	2.938E+01	17.384	2.491E-01	1.180E+02	5.916E-01
10.000	12	104.7	2.938E+01	26.076	2.491E-01	1.180E+02	8.874E-01
20.034	10	42.2	6.078E+01	21.730	5.149E-01	1.180E+02	3.575E-01
20.034	20	84.3	6.078E+01	43.460	5.155E-01	1.179E+02	7.150E-01
20.034	30	126.6	6.078E+01	65.190	5.149E-01	1.180E+02	1.073E+00
50.044	20	32.8	1.547E+02	43.460	1.325E+00	1.167E+02	2.810E-01
50.044	40	65.6	1.547E+02	86.920	1.325E+00	1.167E+02	5.619E-01
50.044	60	98.3	1.547E+02	130.380	1.326E+00	1.166E+02	8.429E-01

APPENDIX 45

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-025 Description : SAMPLE #7 COLD LAKE 150/200 EX 1157

Penetration at 25 C (100/5) :	158	Viscosity at 60 C :	845.0 Poise
10 C (100/5) :	32.5	100 C :	1897.0 cSt
4 C (100/5) :	15.5	135 C :	255.0 cSt
0 C (200/60) :	37.2	150 C :	
45 C (50/5) :			
Penetration Index :	-0.98	Softening Point D36 :	40.0 C
Penetration Ratio :	37.5	Density at 15 C :	kg/L

Test ID : MJG-002 TEST TEMPERATURE : 60.0 C DATE : 88 07 07

Calibration No :	4	Shear Stress :	3.129 Pa/g
Cone :	8	Shear Strain :	2.173 /deg
		Friction :	0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	1	51.2	4.346E+00	2.173	4.244E-02	1.024E+02	5.000E-01
1.998	2	102.7	4.346E+00	4.346	4.232E-02	1.027E+02	1.000E+00
1.998	3	154.4	4.346E+00	6.519	4.222E-02	1.029E+02	1.500E+00
3.000	1	32.2	7.481E+00	2.173	6.748E-02	1.109E+02	2.905E-01
3.000	2	64.1	7.481E+00	4.346	6.780E-02	1.103E+02	5.809E-01
3.000	3	95.9	7.481E+00	6.519	6.798E-02	1.101E+02	8.714E-01
4.999	2	39.3	1.374E+01	4.346	1.106E-01	1.242E+02	3.164E-01
4.999	4	78.8	1.374E+01	8.692	1.103E-01	1.245E+02	6.328E-01
4.999	6	118.1	1.374E+01	13.038	1.104E-01	1.244E+02	9.492E-01
10.000	4	35.4	2.938E+01	8.692	2.455E-01	1.197E+02	2.958E-01
10.000	8	71.2	2.938E+01	17.384	2.442E-01	1.204E+02	5.916E-01
10.000	12	106.9	2.938E+01	26.076	2.439E-01	1.205E+02	8.874E-01
20.034	10	41.4	6.078E+01	21.730	5.249E-01	1.158E+02	3.575E-01
20.034	20	82.5	6.078E+01	43.460	5.268E-01	1.154E+02	7.150E-01
20.034	30	123.8	6.078E+01	65.190	5.266E-01	1.154E+02	1.073E+00
50.044	20	31.9	1.547E+02	43.460	1.362E+00	1.135E+02	2.810E-01
50.044	40	63.4	1.547E+02	86.920	1.371E+00	1.128E+02	5.619E-01
50.044	60	95.5	1.547E+02	130.380	1.365E+00	1.133E+02	8.429E-01

APPENDIX 46

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-030 Description : SPLE #12B 87% COLD LAKE 13% SATURATES

Penetration at 25 C (100/5) : 185
10 C (100/5) : 42
4 C (100/5) : 21.8
0 C (200/60) : 49.3
45 C (50/5) :

Viscosity at 60 C : 686.0 Poise
100 C : 1701.0 cSt
135 C : 245.0 cSt
150 C :

Penetration Index : -0.54
Penetration Ratio : 41.9

Softening Point D36 : 37.2 C
Density at 15 C : kg/L

Test ID : MJG-001 TEST TEMPERATURE : 60.0 C DATE : 88 07 14

Calibration No : 4
Cone 8

Shear Stress : 3.129 Pa/g
Shear Strain : 2.173 /deg
Friction : 0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	1	55.6	4.346E+00	2.173	3.908E-02	1.112E+02	5.000E-01
1.998	2	110.9	4.346E+00	4.346	3.919E-02	1.109E+02	1.000E+00
1.998	3	166.5	4.346E+00	6.519	3.915E-02	1.110E+02	1.500E+00
3.000	2	67.8	7.481E+00	4.346	6.410E-02	1.167E+02	5.809E-01
3.000	4	135.7	7.481E+00	8.692	6.405E-02	1.168E+02	1.162E+00
3.000	6	203.5	7.481E+00	13.038	6.407E-02	1.168E+02	1.743E+00
4.999	3	51.2	1.374E+01	6.519	1.273E-01	1.079E+02	4.746E-01
4.999	6	103.4	1.374E+01	13.038	1.261E-01	1.089E+02	9.492E-01
4.999	9	155.4	1.374E+01	19.557	1.258E-01	1.091E+02	1.424E+00
10.000	5	40.0	2.938E+01	10.865	2.716E-01	1.082E+02	3.698E-01
10.000	10	80.0	2.938E+01	21.730	2.716E-01	1.082E+02	7.395E-01
10.000	15	119.8	2.938E+01	32.595	2.721E-01	1.080E+02	1.109E+00
20.034	10	38.5	6.078E+01	21.730	5.644E-01	1.077E+02	3.575E-01
20.034	20	76.8	6.078E+01	43.460	5.659E-01	1.074E+02	7.150E-01
20.034	30	115.0	6.078E+01	65.190	5.669E-01	1.072E+02	1.073E+00
50.044	50	72.6	1.547E+02	108.650	1.497E+00	1.034E+02	7.024E-01
50.044	100	145.4	1.547E+02	217.300	1.494E+00	1.035E+02	1.405E+00
50.044	150	218.3	1.547E+02	325.950	1.493E+00	1.036E+02	2.107E+00

APPENDIX 47

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP 030 Description : SPLE #12B 87% COLD LAKE 13% SATURATES

Penetration at 25 C (100/5) :	185	Viscosity at 60 C	686.0 Poise
10 C (100/5) :	42	100 C	1401.0 cSt
4 C (100/5) :	21.8	135 C	345.0 cSt
0 C (200/60) :	49.3	150 C	
45 C (50/5) :			
Penetration Index :	-0.54	Softening Point D36 :	37.2 C
Penetration Ratio :	41.9	Density at 15 C :	kg/L

Test ID : MJG-002 TEST TEMPERATURE : 60.0 C DATE : 88 07 25

Calibration No :	4	Shear Stress :	3.129 Pa/g
Cone :	8	Shear Strain :	2.173 /deg
		Friction :	0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	1	60.1	4.346E+00	2.173	3.616E-02	1.202E+02	5.000E-01
1.998	2	119.7	4.346E+00	4.346	3.631E-02	1.197E+02	1.000E+00
1.998	3	180.5	4.346E+00	6.519	3.612E-02	1.203E+02	1.500E+00
3.000	1	34.0	7.481E+00	2.173	6.391E-02	1.171E+02	2.905E-01
3.000	2	68.2	7.481E+00	4.346	6.372E-02	1.174E+02	5.809E-01
3.000	3	103.7	7.481E+00	6.519	6.286E-02	1.190E+02	8.714E-01
4.999	2	34.4	1.374E+01	4.346	1.263E-01	1.087E+02	3.164E-01
4.999	4	68.9	1.374E+01	8.692	1.262E-01	1.089E+02	6.328E-01
4.999	6	103.7	1.374E+01	13.038	1.257E-01	1.093E+02	9.492E-01
10.000	5	39.3	2.938E+01	10.865	2.765E-01	1.063E+02	3.698E-01
10.000	10	78.5	2.938E+01	21.730	2.768E-01	1.062E+02	7.395E-01
10.000	15	117.8	2.938E+01	32.595	2.767E-01	1.062E+02	1.109E+00
20.034	10	37.3	6.078E+01	21.730	5.826E-01	1.043E+02	3.575E-01
20.034	20	74.3	6.078E+01	43.460	5.849E-01	1.039E+02	7.150E-01
20.034	30	111.8	6.078E+01	65.190	5.831E-01	1.042E+02	1.073E+00
50.044	20	28.8	1.547E+02	43.460	1.509E+00	1.025E+02	2.810E-01
50.044	40	57.7	1.547E+02	86.920	1.506E+00	1.027E+02	5.619E-01
50.044	60	104.2	1.547E+02	130.380	1.251E+00	1.236E+02	8.429E-01

APPENDIX 48

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-026 Description : SAMPLE #8 FS-28-83 406 C+ 150 PEN

Penetration at 25 C (100/5) :	150	Viscosity at 60 C :	716.0 Poise
10 C (100/5) :	32.5	100 C :	1290.0 cSt
4 C (100/5) :	18.5	135 C :	155.0 cSt
0 C (200/60) :	38.2	150 C :	
45 C (50/5) :			
Penetration Index :	-0.61	Softening Point D36 :	38.5 C
Penetration Ratio :	39.3	Density at 15 C :	kg/L

Test ID : MJG-001 TEST TEMPERATURE : 60.0 C DATE : 88 07 28

Calibration No :	4	Shear Stress :	3.129 Pa/g
Cone :	8	Shear Strain :	2.173 /deg
		Friction :	0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.999	1	65.1	4.349E+00	2.173	3.338E-02	1.303E+02	4.996E-01
1.998	2	134.2	4.346E+00	4.346	3.238E-02	1.342E+02	1.000E+00
1.998	3	200.3	4.346E+00	6.519	3.255E-02	1.335E+02	1.500E+00
3.000	1	35.3	7.481E+00	2.173	6.156E-02	1.215E+02	2.905E-01
3.000	2	71.3	7.481E+00	4.346	6.095E-02	1.227E+02	5.809E-01
3.000	3	107.0	7.481E+00	6.519	6.093E-02	1.228E+02	8.714E-01
4.999	2	39.9	1.374E+01	4.346	1.089E-01	1.261E+02	3.164E-01
4.999	4	80.0	1.374E+01	8.692	1.087E-01	1.264E+02	6.328E-01
4.999	6	119.2	1.374E+01	13.038	1.094E-01	1.256E+02	9.492E-01
10.000	5	39.0	2.938E+01	10.865	2.786E-01	1.055E+02	3.698E-01
10.000	10	78.3	2.938E+01	21.730	2.775E-01	1.059E+02	7.395E-01
10.000	15	117.3	2.938E+01	32.595	2.779E-01	1.057E+02	1.109E+00
20.034	10	33.0	6.078E+01	21.730	6.585E-01	9.230E+01	3.575E-01
20.034	20	65.9	6.078E+01	43.460	6.595E-01	9.216E+01	7.150E-01
20.034	30	99.1	6.078E+01	65.190	6.578E-01	9.240E+01	1.073E+00
50.044	20	24.9	1.547E+02	43.460	1.745E+00	8.862E+01	2.810E-01
50.044	40	49.4	1.547E+02	86.920	1.760E+00	8.791E+01	5.619E-01
50.044	60	73.6	1.547E+02	130.380	1.771E+00	8.732E+01	8.429E-01

APPENDIX 49

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-026 Description : SAMPLE #8 FS-28-83 406 C+ 150 PEN

Penetration at 25 C (100/5) :	150	Viscosity at 60 C :	716.0 Poise
10 C (100/5) :	32.5	100 C :	1290.0 cSt
4 C (100/5) :	18.5	135 C :	155.0 cSt
0 C (200/60) :	38.2	150 C :	
45 C (50/5) :			
Penetration Index :	-0.61	Softening Point D36 :	38.5 C
Penetration Ratio :	39.3	Density at 15 C :	kg/L

Test ID : MJG-002 TEST TEMPERATURE : 60.0 C DATE : 88 07 04

Calibration No : 4
Cone : 8

Shear Stress : 3.129 Pa/g
Shear Strain : 2.173 /deg
Friction : 0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.999	1	53.7	4.349E+00	2.173	4.047E-02	1.075E+02	4.996E-01
1.998	2	107.7	4.346E+00	4.346	4.035E-02	1.077E+02	1.000E+00
1.998	3	161.6	4.346E+00	6.519	4.034E-02	1.077E+02	1.500E+00
3.000	1	29.7	7.481E+00	2.173	7.316E-02	1.023E+02	2.905E-01
3.000	2	59.6	7.481E+00	4.346	7.292E-02	1.026E+02	5.809E-01
3.000	3	89.7	7.481E+00	6.519	7.268E-02	1.029E+02	8.714E-01
4.999	2	31.1	1.374E+01	4.346	1.397E-01	9.830E+01	3.164E-01
4.999	4	62.3	1.374E+01	8.692	1.395E-01	9.846E+01	6.328E-01
4.999	6	93.7	1.374E+01	13.038	1.391E-01	9.872E+01	9.492E-01
10.000	5	37.1	2.938E+01	10.865	2.929E-01	1.003E+02	3.698E-01
10.000	10	74.4	2.938E+01	21.730	2.921E-01	1.006E+02	7.395E-01
10.000	15	110.9	2.938E+01	32.595	2.939E-01	9.998E+01	1.109E+00
20.034	10	34.4	6.078E+01	21.730	6.317E-01	9.622E+01	3.575E-01
20.034	20	68.9	6.078E+01	43.460	6.308E-01	9.636E+01	7.150E-01
20.034	30	103.1	6.078E+01	65.190	6.323E-01	9.613E+01	1.073E+00
50.044	20	25.9	1.547E+02	43.460	1.678E+00	9.218E+01	2.810E-01
50.044	40	52.1	1.547E+02	86.920	1.668E+00	9.272E+01	5.619E-01
50.044	60	78.0	1.547E+02	130.380	1.672E+00	9.254E+01	8.429E-01

APPENDIX 50

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-027 Description : SPLE #98 90%VIS COLD LAKE 10% NAPH AROM

Penetration at 25 C (100/5) : 178
10 C (100/5) : 38.5
4 C (100/5) : 21.7
0 C (200/60) : 47.2
45 C (50/5) :

Penetration Index : -0.62
Penetration Ratio : 39.2

Viscosity at 60 C : 524.0 Poise
100 C : 1058.0 cSt
135 C : 145.0 cSt
150 C :

Softening Point D36 : 36.3 C
Density at 15 C : kg/L

Test ID : MJG-001 TEST TEMPERATURE : 60.0 C DATE : 88 0/ 1.

Calibration No : 4
Cone : 8

Shear Stress : 3.129 Pa/g
Shear Strain : 2.173 /deg
Friction : 0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	1	55.3	4.346E+00	2.173	3.929E-02	1.106E+02	5.000E-01
1.998	2	110.2	4.346E+00	4.346	3.944E-02	1.102E+02	1.000E+00
1.998	3	165.9	4.346E+00	6.519	3.929E-02	1.106E+02	1.500E+00
3.000	1	24.1	7.481E+00	2.173	9.017E-02	8.297E+01	2.905E-01
3.000	2	48.7	7.481E+00	4.346	8.924E-02	8.383E+01	5.809E-01
3.000	3	73.0	7.481E+00	6.519	8.930E-02	8.378E+01	8.714E-01
4.999	2	25.7	1.374E+01	4.346	1.691E-01	8.123E+01	3.164E-01
4.999	4	51.6	1.374E+01	8.692	1.684E-01	8.155E+01	6.328E-01
4.999	6	77.3	1.374E+01	13.038	1.687E-01	8.144E+01	9.492E-01
10.000	5	29.3	2.938E+01	10.865	3.708E-01	7.924E+01	3.698E-01
10.000	10	59.0	2.938E+01	21.730	3.683E-01	7.978E+01	7.395E-01
10.000	15	88.6	2.938E+01	32.595	3.679E-01	7.987E+01	1.109E+00
20.034	10	28.3	6.078E+01	21.730	7.678E-01	7.916E+01	3.575E-01
20.034	20	56.7	6.078E+01	43.460	7.665E-01	7.930E+01	7.150E-01
20.034	30	85.3	6.078E+01	65.190	7.642E-01	7.953E+01	1.073E+00

APPENDIX 51

SHEAR COMPLIANCE AND VISCOSITY BY CONE & PLATE VISCOMETER

Sample ID : ASP-027 Description : SPLE #9B 90%VIS COLD LAKE 10% NAPH AROM

Penetration at 25 C (100/5) :	178	Viscosity at 60 C :	524.0 Poise
10 C (100/5) :	38.5	100 C :	1058.0 cSt
4 C (100/5) :	21.7	135 C :	145.0 cSt
0 C (200/60) :	47.2	150 C :	
45 C (50/5) :			
Penetration Index :	-0.62	Softening Point D36 :	36.3 C
Penetration Ratio :	39.2	Density at 15 C :	kg/L

Test ID : MJG-002 TEST TEMPERATURE : 60.0 C DATE : 88 07 12

Calibration No :	4
Cone :	8
Shear Stress :	3.129 Pa/g
Shear Strain :	2.173 /deg
Friction :	0.609 g

Load (g)	Rotation (deg)	Cummulative Time (s)	Shear Stress (Pa)	Total Strain	Shear Rate (1/s)	Apparent Viscosity (Pa.s)	Shear Compliance (1/Pa)
1.998	1	38.9	4.346E+00	2.173	5.586E-02	7.780E+01	5.000E-01
1.998	2	76.6	4.346E+00	4.346	5.674E-02	7.660E+01	1.000E+00
1.998	3	114.6	4.346E+00	6.519	5.688E-02	7.640E+01	1.500E+00
3.000	1	22.7	7.481E+00	2.173	9.573E-02	7.815E+01	2.905E-01
3.000	2	44.9	7.481E+00	4.346	9.679E-02	7.729E+01	5.809E-01
3.000	3	67.2	7.481E+00	6.519	9.701E-02	7.712E+01	8.714E-01
4.999	2	24.0	1.374E+01	4.346	1.811E-01	7.586E+01	3.164E-01
4.999	4	47.8	1.374E+01	8.692	1.818E-01	7.554E+01	6.328E-01
4.999	6	71.9	1.374E+01	13.038	1.813E-01	7.575E+01	9.492E-01
10.000	5	28.1	2.938E+01	10.865	3.867E-01	7.600E+01	3.698E-01
10.000	10	56.3	2.938E+01	21.730	3.860E-01	7.613E+01	7.395E-01
10.000	15	84.2	2.938E+01	32.595	3.871E-01	7.591E+01	1.109E+00
20.034	10	26.3	6.078E+01	21.730	8.262E-01	7.356E+01	3.575E-01
20.034	20	52.7	6.078E+01	43.460	8.247E-01	7.370E+01	7.150E-01
20.034	30	79.3	6.078E+01	65.190	8.221E-01	7.394E+01	1.073E+00
50.044	30	30.6	1.547E+02	65.190	2.130E+00	7.261E+01	4.214E-01
50.044	60	61.4	1.547E+02	130.380	2.123E+00	7.284E+01	8.429E-01
50.044	90	92.2	1.547E+02	195.570	2.121E+00	7.292E+01	1.264E+00